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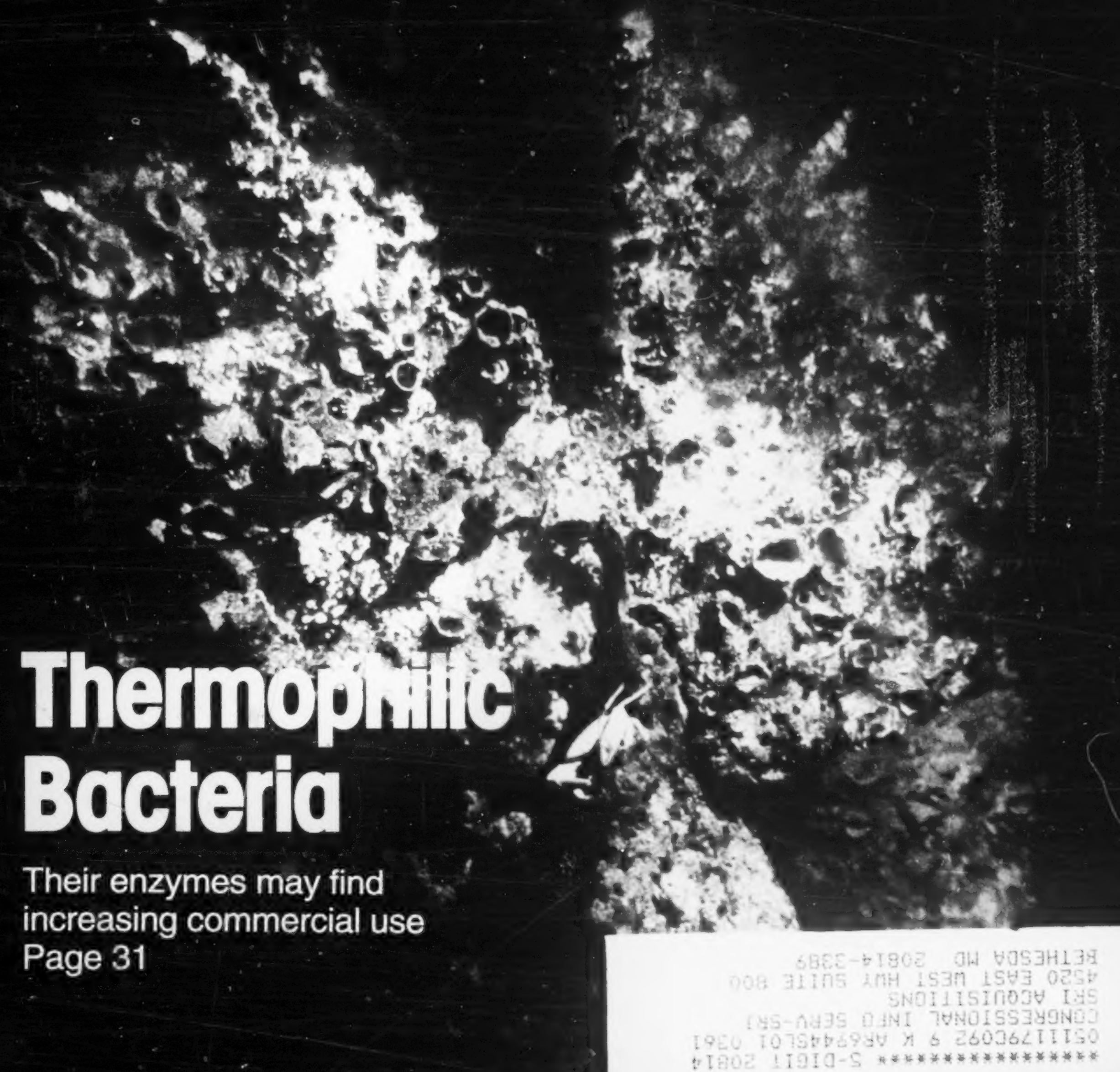
NOVEMBER 4, 1991

CHEMICAL & ENGINEERING NEWS



Thermophilic Bacteria

Their enzymes may find
increasing commercial use
Page 31

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CHEMICAL & ENGINEERING NEWS

Volume 69, Number 44
CENEAR 69 (44) 1–68
ISSN 0009-2347

NOVEMBER 4, 1991

News of the Week

- **Efforts to recruit and retain female, minority, and disabled students in university science and engineering programs fall short of what is needed, according to study issued last week.** Page 6

- **This week, hundreds of chemistry-related groups all over the U.S. will bring chemistry to the public during National Chemistry Week, a huge public relations effort organized by the American Chemical Society.** Page 7

- **French government and Rhône-Poulenc launch five-year, $278 million biotechnology effort focusing on agriculture, chemicals, and human health.** Page 7

- **Federal jury upholds Xoma Corp.'s patent covering use of monoclonal antibodies for treatment of sepsis bacterial infections, and finds that competitor Centocor is infringing the patent.** Page 8

Cover: Hydrothermal vent in Pacific Ocean is typical of sites where thermophilic bacteria have been found. Photo by Holger W. Jannasch, Woods Hole Oceanographic Institution

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Business

Chemical industry growth in Europe is stunted by depressed economy, forcing companies to adopt hard measures; Asia is becoming self-sufficient in petrochemicals; Australian chemical industry embattled by economy, chemophobia, other pressures, maintains long-range optimism; small firm, Genus, bets on its technology for using chemical vapor deposition in electronics applications. **Page 13**

Government

Toxic Release Inventory spawns new laws that increase demands on chemical industry in its reporting of chemical emissions; Congress approves 10% increase for research funding as it struggles to approve appropriations bills for 1992 budget; Bush expected to press Japanese for about $1 billion for Superconducting Super Collider project; scientists assail proposed changes to federal ethics rules, especially attacking rule regarding participation in professional associations. **Page 24**

Science/Technology

BP Chemicals to license its new maleic anhydride process worldwide following successful large-scale trial production; at first Manhattan Poster Project, 36 physical chemistry graduate students shared their research in progress. **Page 34**

People

Milton Harris: a successful professional career and a productive life as remembered by a long-time friend. **Page 42**

Awards

ACS award winners: Sharpless, Berson, Diederich, Dinnocenzo, Dougherty, Hilvert, Hopkins, Ingold, Lerner, Magnus, and Scott. **Page 44**

Cover Story

Bacteria that flourish above 100 °C may provide stable enzymes for catalyzing high-temperature reactions in industrial processing. **Page 31**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
Robert H. Marks, Director, Publications Division
PUBLISHING BOARD: Jean'ne M. Shreeve *(Chairman); Board of Directors Chairman:* Joseph A. Dixon; *President:* S. Allen Heininger; Richard L. Deming; William P. Jencks; Gary J. Long; and Louis D. Quin

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Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
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LETTERS

Tax for fuel economy?

I was intrigued by an item in the Government Concentrates (C&EN, Sept. 23, page 12). A study by the economists of Charles River Associates, paid for by the automakers, concluded that adding a 27.5-cent charge per gal of fuel as a carbon dioxide tax would save more fuel than mandating a fuel efficiency (CAFE) of 40 miles per gal.

It is these types of studies that raise serious questions of credibility. Consider the logic. Instead of truly reducing real consumption and carbon dioxide emissions, we add a tax. As is well understood, most driving is not discretionary. People primarily use their cars for work and that type of driving cannot be curtailed. Thus, consumers would be forced to pay a tax, while continuing their driving habits, which would have no real effect on reducing emissions. But taking the analysis a step further, what would these consumers do? Of course, they would buy cars that get high mileage, such as those that get 40 miles per gal. Consider the effect of the shortage in 1973. The automobiles highest in demand were either the Honda Civic or the diesel Rabbit, which was rated at 50 miles per gal. Thus, the market will force the automakers to meet the CAFE limits regardless of the regulation. The net effect, of course, would be that in the interim even with 40-mile-per-gal cars, consumers would be paying an additional 27.5 cents per gal.

This study makes no sense unless one considers the automakers' objective. They do not want to be forced to meet CAFE standards. How to avoid it? Present a new tax on fuel before the government, cloaking it in the garb of being an environmental necessity. By making this a "credible" alternative, automakers can "buy" their way out of the regulation with taxpayer dollars.

The sad part of this is that it may work. With Washington starved for revenue, and the environmental cause being one of the hot buttons that our politicians wish to associate with, our legislators may accept the rationale regardless of the fact that it is counterproductive.

A Japanese manufacturer has recently introduced a new car that does, in fact, get 50 miles per gal and does so with performance and style. CAFE or no CAFE, the American automakers will continue to lose market share.

I am grateful that I am associated with the chemical industry, because regardless of the public perception, I have always found chemical industry professionals to be truly concerned about their social responsibilities and am sure those same professionals would not stoop to producing studies such as this one as a way to avoid regulations. The automakers simply have not learned that the short-term benefits to these manipulations are really no benefit at all.

William J. Sapone
New York City

Noninterview remembered

In view of the present furor aroused by the Judge Clarence Thomas hearings, you might be interested to know that 31 years ago an industrial outfit in the Boston area invited me for an interview for a position as a chemist.

When I appeared, the interviewing chemist shook my hand, looked at me in silence for 10 seconds, and said, "Goodbye Dr. Gleiser." As soon as I reached home—boiling mad—I called him and asked him the meaning of my noninterview. He replied, "I just wanted to see what a 90-pound female Ph.D. chemist looked like."

I have long since forgotten this gentleman's name. But perhaps he would like to stand up now and take a bow.

Molly Gleiser
Berkeley, Calif.

Appointment in Samarra

You had a story on the visit of United Nations inspectors to Iraq's largest chemical weapons facility at Samarra (C&EN, Aug. 5, page 5). Apparently, the UN team has an appointment to return for a further inspection in September.

It is curious that a facility dealing in death should be located in this ancient city, the scene of a well-known Arab tale of the inexorability of fate: A servant in Baghdad saw Death in the marketplace, personified by a woman who made a menacing gesture. Frightened, he borrowed his master's horse and rode as fast as he could to Samarra to escape his fate. Later, the master saw Death in the marketplace and asked why she had threatened his servant. She answered, "I didn't threaten him. I was simply aston-

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Depressed European Economy Mires Chemical Industry Growth

But overcapacity will be averted as mature business with too many companies is forced to adopt hard measures, cut back expansion

It didn't take too many market-research crystal balls to give the obvious answer: The European chemical industry is mirroring the state of the European economy, whether in Western or Eastern Europe or the Soviet Union.

The West European economy has undergone "substantial change" in the past 18 months, noted Richard Freeman, corporate chief economist at ICI, at the recent meeting of ECMRA, the European marketing research group, in London. "After several years of strong growth, real gross domestic product (GDP) in many countries slowed down sharply around mid-1990, and the slowdown gathered pace in the first half of this year."

There are some glimmers of hope, however. "With the main exception of Germany," he said, "demand and activity in Europe now seem to be strengthening again, although the recovery will be rather weak and drawn out."

Western Europe's average GDP was growing at more than 4.5% per year in 1987. By 1990, however, that growth dropped to 2.8%, and this year is expected to decline further to only 1.4% over last year. General economic growth in 1992 is forecast to be only a little over 2% over 1991.

Meanwhile, in Eastern Europe the economies are even more depressed, and output is expected to continue to fall for the next two or three years at least.

In a way, that may help the European chemical industry. Too much growth could overstimulate capacity additions, according to Peter Vogtländer, chemicals coordinator for Shell International Chemical Co.

The scars from the massive cutbacks in the industry in the early 1980s may still be felt by now senior executives, he said, but "we are seeing a repetition of the early 1980s. For a mature business, there are too many players; we see some new players coming in as well. The industry will have to sort itself out."

One potential answer, he suggested, is that a number of firms that had been holding on from 1987 to 1989 because they were making money, not because the businesses were "core," will now swap portfolios, or go out of these businesses altogether.

"Companies will be forced to cut back expansion plans," Vogtländer predicted. "Do chemical companies want to have a lot of blood on the table? That doesn't get them anywhere. They will have to make decisions. The senior people in the companies now lived through the miseries of the early 1980s. Now people are willing to take harsh measures, earlier. I don't think the senior people will have the same optimism as they had in the 1980s, that things will get right in a few months."

He touched on the opening up of Eastern Europe: "The opportunities and risks [for Western European producers] will be tremendous. Forecasts seem to include the positive impact on demand from these countries, but seem to ignore the potential impact on supply. Isn't it logical and prudent to assume that not all of the extra demand for petrochemicals in this part of the world will be imported from the West and that, in many of the East European countries, plants will be built?"

Soviet output of polymers has risen, but trails demand

	% change 1985–90	Production as % of demand
Polyethylene	3%	57%
Polypropylene	37	55
Polystyrene	12	60
Polyvinyl chloride	46	65
Synthetic fibers	6	86
Synthetic rubber	–3	93

Source: Moscow Institute of Applied Biotechnology

However, for a significant period in the future, there will still be ample opportunity for western companies to supply the Eastern European markets, said Vladimir Vakula, professor at the Moscow Institute of Applied Biotechnology.

"When the Iron Curtain disappeared, a new curtain appeared—currency," he said. "It is very effective, although not as dense as the other." This has been one of the main reasons for a changing and deteriorating situation in the Soviet chemical industry over the past two years and into the first half of 1991.

As in Western Europe, the chemical industry has mirrored the parlous state of the general economy. According to Vakula, in the first half of this year, the Soviet gross national product (GNP) has fallen 10% and productivity 11% from first-half 1990. In June 1991, industrial production was down 9% from June 1990, with drops for 127 out of 156 products for which official statistics are collected.

One of the reasons for the continuing economic problems, he said, remains the militarization of the national economy—25% of GNP is accounted for by military expenditures, and in the engineering sector, 80% of production is assigned to military.

"Industry works for its own sake, rather than for the customer's needs," said Vakula, with only 25% of GNP going into consumer goods.

Cooperation between supplier and customer is almost nonexistent, and is not considered important, he noted. In fact, in 1989, one half of all supply contracts were not fulfilled.

According to Vakula, in the years from 1985 to 1990, there was a continuing rise in the growth rate for production. But year to year, the rate has been falling. Many products don't come close to meeting domestic demand, although capacity utilization is relatively high. However, outmoded plants and equipment have hindered production expansion, and the country has not kept up in its bid to modernize. Only about 60% of planned capital spending for the five-year period was actually spent.

There are many incentives, he believes, for western companies to invest. First, the Soviet chemical industry is the third largest in the world, "and it is still functioning." "The share of chemicals is only 6.3% of total industrial production, and it should be 10 to 12%." Another major plus is the country's serious R&D potential; it has more than 100 research institutes, with 100,000 employees, as well as the Soviet Academy of Sciences and the institutes of higher education.

"The U.S.S.R. suffers from a shortage in all products the chemical industry supplies. Hence, western investors targeting construction of production units or plants do not have to be worried about competition for at least the next five to 10 years," he added.

Patricia Layman

Asia becoming self-sufficient in petrochemicals

Because of the high growth rate of Asian industry, the global petrochemical industry has become tripolar in demand, centered in the U.S., Europe, and now Asia. To meet that demand, the production picture is changing, too: The Asian region, once a large net importer of petrochemicals, is gradually becoming self-sufficient.

Yoshio Tokuhisa, managing director for strategic and corporate planning at Mitsubishi Petrochemical Co. in Tokyo, drew that picture of the Asian chemical industry at the recent meeting of the European marketing research group ECMRA in London. But he pointed out that production in Japan and in Southeast Asia is increasing so rapidly that many industry observers are concerned that the region is embarking on the same kind of overbuilding that occurred in Western Europe in the late 1970s in basic petrochemicals. The result, lasting into the mid-1980s, was a glut of product and abysmal operating and profit figures.

Not all the Japanese ethylene projects that have been proposed will be built, he predicted. "I think there is a high possibility that we in Japan can avoid extreme excess capacity. We are not terribly happy, but the situation is bearable."

However, there is a major likelihood of Asian overcapacity because of projects under way or proposed in South Korea. "The thought of the Korean petrochemical industry raises my blood pressure and gives me a headache," says Tokuhisa.

Since a substantial amount of South Korean products are likely to be exported, the negative impact on the global, particularly the Asian, petrochemical industry will be enormous, Tokuhisa explained. Japan will be particularly hard-hit, especially in the short-term, with a decrease of up to 2% on profit margins—an annual loss of $400 million to $600 million in profits from the whole Japanese petrochemical industry—and a loss of some of the country's existing markets in Korea and China.

However, the impact will be diluted after that, as world growth in demand absorbs the production.

One of Tokuhisa's concerns is the significant forward- and backward-integration in the South Korean petrochemicals business. Derivative producers who used to purchase ethylene are now producing, and ethylene producers are also moving into derivatives production. "This combination has led to . . . enormous excess capacity," he said.

In 1988, South Korean ethylene capacity was 500,000 metric tons per year, and by 1993 it is expected to hit 3.2 million—more than six times that in 1988. By contrast, in Western Europe, ethylene capacity in 1993 is expected to be 1.2 times that in 1988, in the U.S. 1.3 times, and in Japan 1.4 times.

"On top of this, some large group companies with almost no experience in the petrochemical industry are also entering the business, constructing both upstream and downstream facilities concurrently," Tokuhisa notes. Key examples are Samsung and Hyundai, which are each building 350,000 metric ton-per-year ethylene crackers, to be finished by the end of this year. "It is like Sony Petrochemical and Toyota Petrochemical being established at the same time," he adds.

By Mitsubishi's calculations, profits for all the South Korean industrial groups—shipbuilding, watches, electronics, and so on—will be almost exactly offset by their losses in petrochemicals. This factor led Tokuhisa to predict that the South Korean government would be forced to step in with rescue aid.

That kind of overcapacity inevitably signals a price war spreading throughout western markets, Tokuhisa said, as Korean products seek purchasers. "They will export to the U.S., probably not to Europe or the Middle East. A price war is already starting to happen," he added. "Japanese prices are relatively high, and Korean producers are trying to enter our market, but they are finding it very difficult. So they are trying to enter other Southeast Asian countries, or the U.S."

Besides the Korean projects, others have been announced in the Asian region. Among them: two in Taiwan, for a total of 850,000 metric tons per year; one in China, at 380,000 metric tons; a second cracker in Thailand, with 350,000 metric tons; cracking capacity in Indonesia of 550,000 metric tons; and a cracker in Malaysia, with 320,000 metric tons. That's a total of 2.45 million metric tons per year of announced capacity, most to be operating in 1994–95.

"Even if we assume that only half of them will materialize, the impact will still be enormous," Tokuhisa said.

Tokuhisa did not include another capacity addition, in Singapore. But according to Siau-Chua Lim, the U.K. director for the Singapore Economic Development Board, Singapore is encouraging projects at the high-value-added end of the petrochemical chain, to get away from too much economic reliance on basics.

All told, the Singapore chemical industry had sales of $9.9 billion in 1990, Lim said, giving a brief description of the industry: 175 international and local companies in this sector, employing 13,000 people, and growing at an average of 15% per year from 1975 to 1990. It is the second largest manufacturing sector there, accounting for 25% of total manufacturing output, after electrical equipment.

The country's refining industry accounts for about 10% of the total primary refining capacity in Asia, and has evolved to be what Lim calls the swing refining center in Asia.

"The strong refining base led us to the petrochemical industry in the early 1980s. The Singapore petrochemical complex was the first in Southeast Asia, costing then $1 billion," he said. The project was a joint venture between the Singapore government, which has since sold most of its share to Shell, and a consortium of mostly Japanese companies, led by Sumitomo Chemicals. The complex uses both naphtha and liquefied petroleum gas as feedstock, to produce 400,000 metric tons per year of ethylene, 200,000 of propylene, and 150,000 of benzene, toluene, and xylenes.

Monomers are fed to seven downstream companies, producing linear low-density polyethylene, high-density polyethylene, polypropylene, ethylene oxide and ethylene glycol, ethoxylates, methyl-methacrylate butadiene styrene, methyl *tert*-butyl ether, and acetylene black.

"At the time the project was conceived, there were great uncertainties about the world economy, and the petrochemical industry in America and Europe was in disarray and under major restructuring," Lim pointed out. "But my government thought the strategic factors for the project were sound. . . . The initial years were indeed difficult. The market turned around in the mid-1980s, and the complex became quite profitable from then on."

There are now plans to expand the complex, noted Lim. "The output of the sector reached $1 billion last year—not a bad achievement, considering that the industry was virtually nonexistent 10 years ago." Since its startup in 1984, the petrochemical complex has expanded to its limit through debottlenecking and more downstream projects, he noted, and there are preliminary plans to double the capacity.

Expansion is expected to be completed in 1995, and will cost $1.5 billion. Besides more petrochemicals, it will also add new derivatives capacity. For example, it will include engineering plastics and specialty fibers abd aromatics and oxo-chemicals.

Patricia Layman

Australian chemical industry battling adversities

This year has been characterized as a "doom year" for Australian chemical manufacturers. But as bad as things look now, there is still long-range optimism, fueled by a hardiness that seems as native to Australia as the outback.

Richard Warburton, vice president of the Australian Chemical Industry Council (ACIC) and managing director of Du Pont (Australia), observes that in 1989 profits dropped 30% and sales dropped 15%. Performance was equally bad in 1990, and few signs have emerged that matters will get any better very soon. The most negative effects may be decreased attractiveness for investment in high-technology and value-added industry.

Investment in new plants has fallen off during the past two years. The primary reason, Warburton says, is persistent overcapacity. To compound the problems, capital costs in Australia are among the highest in the world and chemical imports have doubled during past five years. Probably the most prominent problem is a wave of extreme chemophobia that has swept over Australia. Despite demonstrated high safety standards and compliance, the Australian chemical industry does not presently enjoy popular acceptance.

The government may not be helping the situation. According to Frank V. Phillips, chief executive officer of ACIC, last spring the Australian government issued an industry statement that had some negative effects. Phillips says tariff reductions combined with a failure to deliver on some basic economic reforms have done little to buoy the spirits of the industry. The maximum tariffs for chemical imports will drop from 15% to 5% in the next few years. Before 1987 tariffs were as high as 45%.

Phillips and ACIC suggest that some of the needed reforms are a more modern infrastructure, espe-

Australian chemical industry: its 1990 performance . . .

$ Millions (U.S.)		% change from 1989
Sales	$ 3,630	−9.3%
Trading profits	330	−46
After-tax profits	132	−59
Exports	413	8.4
Imports	2,560	—
R&D expenditures	40.3	3.3
Environmental protection expenditures	46.3	1.8
Employment	11,175	−8.1
Operating capacity	88.2%	−2.3

. . . and its plans for expansion

	Committed projects		Possible additions	
$ Millions (U.S.)	1 year	3 years	1 year	3 years
New plants^a	$231.4	$451.2	$27.3	$238.0
Improvements in existing plants^a	124.8	292.6	10.7	54.5
TOTAL	**$356.2**	**$743.8**	**$38.0**	**$292.5**

Note: Dollar amount based on $1.00 U.S. = $1.21 Australian. a Data for basic industrial chemicals and synthetic resins; fertilizer manufacture is excluded. **Source:** Australian Chemical Industry Council cially with respect to waterfront and coastal shipping; better land transport; and more enlightened labor policies. A particularly strong recommendation is for a more broadly based consumption tax.

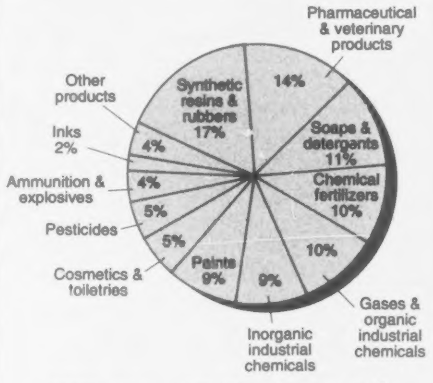
Among the positive features of the government's industry statement were the removal of Singapore, Taiwan, Hong Kong, and South Korea from preferred trading status and an improvement in depreciation allowances. The government has also decreased to a maximum of 40 days the time required to rule on dumping actions. Environmental impact statement expenditures have been made tax deductible, and the deduction for R&D expenses will remain at 125% at least until 1993.

A problem that has grown serious since 1989 is the training of personnel for the chemical industry. A bewildering maze of national and state training offices may be sometimes purely advisory and sometimes more authoritative. Consequently, conflicting recommendations can ensue, and the industry keeps a close watch to ensure that "the training agenda of these agencies is not dominated by the bureaucracy."

The matter of training is closely tied to the wage-realization structure. In the state of Victoria, for example, a certificate in chemical plant operations-chemical processes, obtained from an approved course of instruction, affects future pay classification. Similarly at the national level, certified instruction in chemical plant operation is under development by the colleges. At the end of 1991 the certification procedure from Victoria is supposed to be merged into the national procedure, but this may not eliminate the bureaucratic confusion.

If training professional personnel to operate the chemical industry is a major problem, even more vexing is educating the public to view the chemical industry from a more realistic perspective. A current drive by the industry to gain public understanding is typified by the Responsible Care program being managed by ACIC, which represents about 95% of the Australian chemical makers.

Australian chemical industry sales break down this way



1990 sales = $7.68 billion (U.S.)[a]

[a] Based on $1.00 U.S. = $1.21 Australian.
Source: Australian Bureau of Statistics

These chemical makers directly employ about 10,000 people and, indirectly, about double that number.

ACIC's Responsible Care, like the Chemical Manufacturers Association's Responsible Care program in the U.S., was adapted from a similar program begun by the Canadian Chemical Producers Association in the mid-1980s. It began in Australia in late 1989 and is scheduled to be completely implemented by 1993. The objective is to demonstrate responsible operation of plant facilities in compliance with regulations and good practice and to improve operation where possible. This is to be done with the cooperation of and in full view of the public. In fact, the industry has been doing exactly this for some time, but the public's chemophobic attitude requires more dramatic measures to prove it.

In the spring of 1992, ACIC will conduct its third Industry Open Door. About 40 major chemical plants will host 40,000 visitors and explain the operations to anyone with questions and interests. The immediate purpose is to "demystify" the view of the industry often held by the visitors and to demonstrate the industry's importance. Ideally the Open Door will also help promote potential careers in the industry by interested young people. Previous Open Doors were held in 1987 and 1989.

Much of the chemophobia in Australia is attributed by industry leaders to Greenpeace activists and similar groups. According to a number of industry spokesmen, the "misinformation" of these groups has been disseminated by "largely uncritical media." A celebrated incident occurred in May 1990, when Greenpeace attempted to block a discharge pipe from Nufarm Co., a pesticide maker near Melbourne. According to ACIC's Phillips, in a letter to *Chemistry in Australia*, Greenpeace claimed that the discharge contained dioxin levels 100 million times higher than U.S. safety standards. These levels, claimed Greenpeace, represented the most serious toxic-waste problem the environmental organization had encountered in Australia. Subsequent media publicity shed little light, but emotions were inflamed.

Eventually the discharge was thoroughly tested by independent analysts and declared not to be a hazard. Similar views then were voiced by several investigative reporters. The Melbourne Metropolitan Board of Works also issued a statement that Greenpeace had misled the public. It seemed that Greenpeace had been thoroughly discredited in this episode. However, Greenpeace responded further with the claim that the Board of Works had continued to ignore the contamination levels and that some chemical companies—for example, Monsanto and BASF—had fabricated basic data on the dioxins that are often cited in regulatory proceedings.

Chemical industry executives in Australia give the impression that the industry is embattled but hardly ready to capitulate to economic pressures or environmental activist opponents.

A perennial problem for the Australian chemical industry is foreign ownership. Most of the major chemical companies are based in Europe, Japan, or the U.S. That offers much-needed capital acquisition for a market of about 17 million people, but it also tends to severely limit the very high potential for home-grown research and development that could improve Australia's export position.

Joseph Haggin

R&D funds up 10% in 1992 appropriations bills

It's become an annual rite of autumn. Federal agencies operating under a continuing resolution because as of Oct. 1, the mark of the new fiscal year, Congress had not completed work on the 13 appropriations bills needed to keep the government in funds. At press time the majority of the bills were on their way to the White House for signing. But the two that provide money for the largest research-sponsoring agencies—the departments of Defense and of Health & Human Services—were lagging far behind their counterparts.

So far research funding has fared better than might have been expected in the first year under the binding budget agreement worked out late last year between the Administration and Congress. That agreement allowed overall funding for domestic programs to grow enough to recover buying power lost to inflation, which is currently running at about 2%. However, Congress has approved an overall increase of 10%, to $17.4 billion, for the six research-sponsoring agencies whose fiscal 1992 budgets are now in place.

In many cases, Congress increased research funding, but by less than the Administration wanted. The National Aeronautics & Space Administration's research budget is a case in point. It's up 6% to $6.4 billion, still ahead of inflation, but the Administration was looking for a 20% increase to $7.2 billion. Congress did provide the full budget request of $2 billion for the space station program and capped fiscal 1993 funding for the program at $2.3 billion.

Overall funding for the National Science Foundation is also up 11% to $2.6 billion. However, Congress once again rebuffed the Administration's plan, which first surfaced during former President Reagan's term, to double funding for NSF research programs over five years. Research and related programs are up 11% to $1.9 billion, compared with the 16% increase the Administration had sought. However, it got more than the 21% increase it wanted for NSF's education and human resource activities, with Congress' approval of a whopping 44% increase to $465 million for those programs.

The Department of Energy fared better than either NASA or NSF. Overall funding for its research programs is up 14% to $4.3 billion. However, funding for basic energy sciences is up only 7% to $765 million, with funding for chemical sciences frozen at $158 million and that for materials sciences down 6% to $257 million.

Energy's fiscal 1992 R&D budget, as usual, presented a particular target of opportunity for another annual ritual—earmarking research funds for specific projects, many with no apparent connection to the work of the agency that is providing the funding. For example, out of the department's energy supply R&D budget Congress set aside funding for these projects:

- $10 million for the Institute of

Energy R&D, NSF education programs fare well as Congress approves 1992 budgets

	1992			% difference	% change
$ Millions	Appropriation	Request	1991	Appropriation-request	1991-92
NASA R&D	**$ 6,413.8**	**$ 7,198.5**	**$ 6,023.6**	-11%	6%
Energy	**6,177.4**	**5,783.4**	**5,447.1**	7	13
Energy R&D	**4,251.2**	**4,031.2**	**3,717.3**	5	14
General science and research	1,472.5	1,548.9	1,148.7	-5	28
Basic energy sciences	764.7	714.7	711.7	7	7
Materials sciences	257.1	257.1	274.9	0	-6
Chemical sciences	158.3	158.3	157.6	0	0
Fossil	450.1	227.0	458.8	98	-2
Environment	353.3	312.6	393.9	13	-10
Fusion	337.1	337.1	273.6	0	23
Nuclear	332.0	398.0	304.0	-17	9
Conservation	299.8	290.9	228.3	3	31
Solar, other renewables	241.7	202.1	198.3	19	22
Defense R&D	**1,926.2**	**1,752.2**	**1,729.8**	10	11
Weapons	1,231.0	1,074.0	1,077.8	14	14
Naval reactor development	695.2	678.2	652.0	2	7
NSF	**2,574.0**	**2,718.5**	**2,313.0**	-5	11
Research and related activities	1,879.0	1,963.5	1,694.2	-4	11
Education and human resource activities	465.0	390.0	322.3	19	44
Antarctic activities	88.0	193.0	175.0	-54	-50
Salaries and expenses	109.0	122.0	101.0	-11	8
Academic research facilities and instrumentation	33.0	50.0[a]	20.5[b]	-34	61
USDA	**1,397.8**	**1,279.1**	**1,281.6**	9	9
Agricultural Research Service	658.4	660.6	621.6	0	6
Cooperative State Research Service	430.7	384.2	388.5	12	11
Forest Service research	182.8	163.2	167.6	12	9
Building and facilities	125.9	71.1	103.9	77	21
Commerce	**544.4**	**529.3**	**513.0**	3	6
Oceanic and atmospheric research	209.3	187.0	206.7	12	1
NIST[c]	246.7	248.0	215.3	-1	15
PTO[d]	88.4	94.3	91.0	-6	-3
EPA R&D[e]	**323.0**	**313.0**	**254.9**	3	27
TOTAL	**$17,430.4**	**$17,821.8**	**$15,833.2**	-2%	10%

a Money requested for facilities only. **b** Funds appropriated for instrumentation. **c** National Institutes of Standards & Technology. **d** Patent & Trademark Office. **e** Does not include intramural research funds. **Source:** Appropriations Committees' reports

Micromanufacturing at Louisiana Tech University, Ruston.

- $10 million for an ambulatory research and education building at the Oregon Health Science University, Portland.
- $10 million to expand the Energy, Mineral & Materials Science Research Building at the University of Alabama, Tuscaloosa.
- $10 million for construction of a research institute at California's Loma Linda University Medical Center.
- $10 million for construction of a cancer research center at Indiana University School of Medicine, Indianapolis.
- $10 million for construction of the Old Colony Center for Technological Applications at Bridgewater State College in Massachusetts.
- $10 million for the Center for Molecular Electronics at the University of Missouri, St. Louis.
- $6 million to complete the Biomedical Research Institute for Louisiana State University's Medical Center in Shreveport.
- $4.8 million for the Medical University of South Carolina's Cancer-Oncology Center.
- $4 million for the Technology Complex at Pittsburg State University in Kansas.

Janice Long

Japan ponders support for U.S. supercollider

President Bush is expected to press for Japanese support for the Superconducting Super Collider (SSC) when he meets with the new Japanese Prime Minister, Kiichi Miyazawa later this month.

Bush won't have an easy time of it, however, because Japanese sources say Miyazawa will be asking Bush some tough questions about just why the U.S. thinks the controversial machine is all that important for science and for relations between the U.S. and Japan—especially in light of significant sentiment in Congress to kill it.

The question of Japanese support for the big collider serves to highlight many of the trade, investment, and attitudinal strains between the two countries. "Miyazawa will have to convince a lot of his ministers that the collider is important for overall relations between Japan and the U.S.," says one source. "There will be some hard bargaining" over other areas of cooperation, such as in education and technology transfer, says the source. Adding to Miyazawa's difficulties will be new Japanese resistance to U.S. demands that it change its ways.

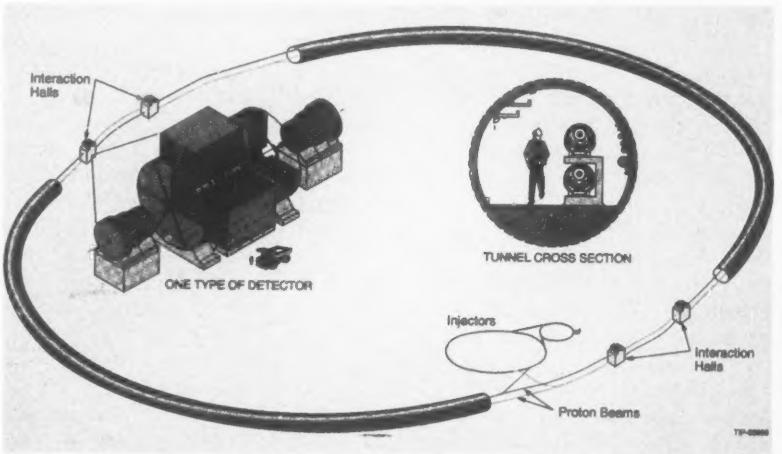
Although the original cost of the 40 trillion eV accelerator was put at $5.5 billion when the Administration first announced plans to build it in 1987, current estimates now run to about $10 billion. Last year, the Department of Energy asked Japan for $2 billion in SSC support, but that request has been scaled down to something from $600 million to $1 billion over five years or so in the form of direct grants, equipment contributions, construction assistance, superconducting magnet development, and instrumentation.

Japan has resisted participation for two predominant reasons. One, it was never promised any kind of role in planning and administering the project, and two, it has its own scientific needs to meet in a domestic science budget that is perpetually tight. The infrastructure of Japan's universities is considered among the worst in the industrialized world, and for Japan to take its place as a major global contributor to basic research, the universities need a massive infusion of capital. SSC support, Japan's academic leaders fear, would seriously cut into the help they are hoping to get from the new Miyazawa government. Miyazawa already has been told that a special fund for the SSC will have to be set up before Japan's science community consents to SSC support.

Last month, Bush's science adviser, D. Allan Bromley, outlined a series of concessions to the Japanese in hopes of breaking down their resistance. He told Japan's Science Council he was offering Japan an "equity position in the construction and operation of the SSC" whereby Japan would be involved in the SSC's planning, construction, and management. "This proposal," he said, "marks a new approach to the construction and operation of a major international science project. We need your country as a partner if this is to occur."

Bromley also suggested the Japanese approach supporting the SSC in the same way the U.S. did: Tie it to increasing funds for academic basic research. Combining the two, said Bromley, would bring Japan's science to the international level of its technology.

Bromley embellished his plea with offers to support current Japanese thrusts in international science and technology projects. One such initiative is the Human Frontiers Science Program, which funds international research in basic biology, a



Artist's rendition of Superconducting Super Collider lab

NOVEMBER 11, 1991

CHEMICAL & ENGINEERING NEWS

Chemical company earnings continued to drop in third quarter
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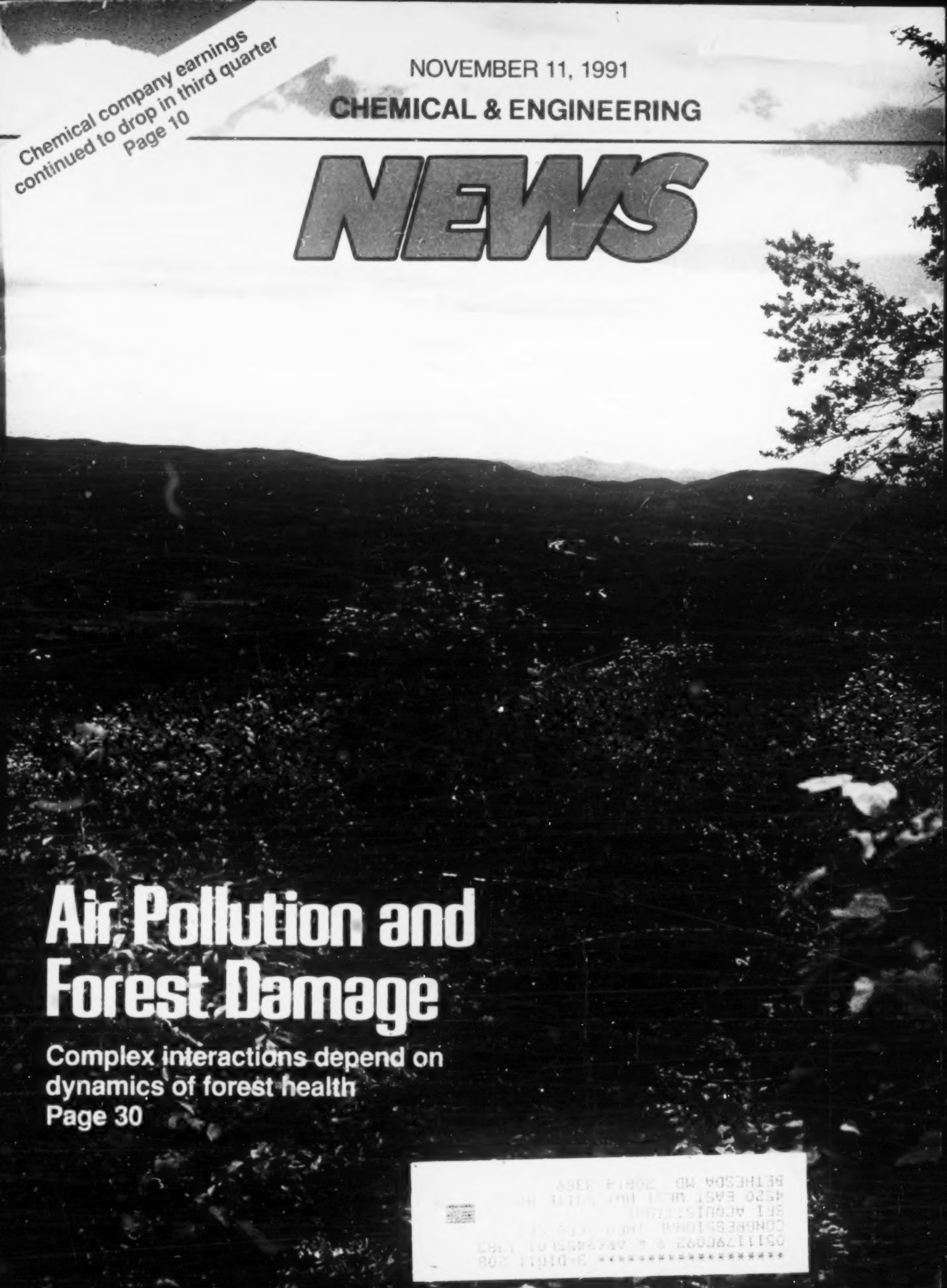

Air Pollution and Forest Damage

Complex interactions depend on dynamics of forest health
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CHEMICAL & ENGINEERING
NEWS
NOVEMBER 11, 1991

Volume 69, Number 45
CENEAR 69 (45) 1–60
ISSN 0009-2347

News of the Week

- **In a deal with the White House, Congress has revived the controversial Critical Technologies Institute just two months after the Administration asked that the idea be killed.** Page 4
- **The NMDA receptor, a protein that plays a key role in nerve transmission and in disorders like epilepsy and stroke, has been cloned and characterized in rats by Japanese researchers.** Page 5
- **A record fine of $10 million levied by OSHA will be paid by IMC Fertilizer and Angus Chemical for alleged safety and health violations related to a nitroparaffins plant explosion.** Page 5
- **NSF's advisory committee for chemistry criticizes the new Presidential Faculty Fellows program, fearing politics and prestige will outweigh scientific merit in the selection process.** Page 6

Business

Earnings of major chemical companies continued to fall in the third quarter, marking the ninth straight quarter of decline. **Page 10**

Major changes are under way in the pulp and paper industry that will affect consumption of chemicals. **Page 15**

Australian chemical industry faces some tough problems, particularly a very unfavorable attitude from the public. **Page 16**

Government

NSF's chemistry division proves resourceful in creating ways to stretch its grant support as division faces yet another disappointing funding increase. **Page 19**

Science/Technology

New university in Hong Kong aims to offset brain drain and bolster industrial growth as colony faces reintegration into China. **Page 26**

Role of undergraduate research in chemical education is focus of Dutch symposium to be held later this month in Amsterdam. **Page 28**

Spacecraft Magellan yields dramatic views of Venus' landscape, showing volcanoes and craters in three dimensions. **Page 29**

Cover: Northern hardwood forest in Hubbard Brook Experimental Forest, central New Hampshire. Photo by William H. Smith, Yale University

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Special Report

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
Robert H. Marks, Director, Publications Division

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Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
(For list of offices see page 59)
Office of Ombudsman: (800) ACS-5558, No. 8-5
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LETTERS

Universal symbol

In a letter to the editor (C&EN, Sept. 9, page 2), John Cox urges ACS to attempt to develop a generally recognizable generic symbol for "chemicals." ACS has in place a committee dedicated to problems of nomenclature, symbols, and pronunciation; it maintains a close liaison with the International Union of Pure & Applied Chemistry, which is dedicated to such concerns.

Those readers who have thoughts, as well as creative suggestions, pertinent to this concern are invited to send them along to the undersigned member of the ACS committee, or, more appropriately, to the committee's chairman, Peter A. S. Smith, Department of Chemistry, University of Michigan, Ann Arbor, Mich. 48109.

Jack H. Stocker
Department of Chemistry
University of New Orleans
New Orleans, La. 70148

I was appalled by the publication of the letter on a universal symbol for chemicals by John L. Cox . One of ACS's aims is to aid the public in understanding that chemicals are omnipresent and are not found only in laboratories, factories, and toxic waste dumps. A request by a single fellow ACS member for a "universally recognized chemical symbol" is surprising, but seeing it in print in this magazine makes one wonder if the educational process needs to begin in our own ranks.

Fred C. Frederick
Roanoke, Va.

Licensing chemists

I must respond to, and rebut, many of the points raised in William A. Levinson's letter (C&EN, Aug. 19, page 5) regarding licensure of chemists. The public's perception of the benefits and detriments of materials, drugs, and chemicals combined, is based on ignorance, hearsay, and sales pitches. Drugs for chemotherapy are highly potent and are toxic. However, the benefits they offer clearly outweigh their risk—but this does not diminish the care with which they must be handled. All drugs are hazardous if used improperly.

As far as chemicals go, the public is sensitized to chemical spills and hazards, not benefits. The tragedies make the front page. The value to society is rarely a front-page affair. Society expects these benefits as a matter of course. I'm sure that if a new chemical plant, of whatever form or size, were to be sited in my community, the first question asked about the venture would not be in regard to the increased tax base, the number of jobs produced, or the gains to society that could be realized. Rather, it would relate to the toxic effects of plant operations, real or imagined.

The basic distinction between a licensed profession, such as medicine, law, or private engineering, versus an unlicensed profession, such as chemistry, is the concept of private practice. This concept is that of a professional offering his or her services directly to the public at large for a fee. If John Q. Public walks into Dr. X's office, there must be a level of trust between the two, since John Q. is not a doctor. If I, as a chemist, opened an office and hung my degrees on the wall, I would spend most of the day reading *Chemical & Engineering News* and staring at my degrees. There are very few opportunities for me to offer my research services directly to the public. We license truck drivers, because although truck driving does not require an advanced degree, it does require a special set of skills (such as those for certification) and truck drivers may offer their services directly to the public (as independents).

The argument that licensure of chemists would cut industrial costs is absolutely ludicrous. It is analogous to stating that, because doctors are licensed, health care and malpractice costs are contained! I suppose we could set up our own coterie. Then, we could get our salaries up to the level of M.D.s. I see that we already have a large degree of prestige (C&EN, Sept. 2, page 30); perhaps we could raise that as well. By the way, who would cover my malpractice insurance?

Levinson, why do you make the distinction that only chemists "whose jobs affect worker or public safety" be licensed? Who is exempt? Of course, all professors with graduate students must be licensed, since they would be involved with "worker safety." Perhaps we could exempt theoretical chemists, since they don't actually work with com-

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Chemical Earnings, Profitability Tumble Again in Third Quarter

William J. Storck,
C&EN Northeast News Bureau

It has been nine straight quarters of declining earnings for the chemical industry. The third quarter of 1991 continued the story that has been unfolding since the middle of 1989 of declining demand, overcapacity in some areas, and prices that do not necessarily cover costs—especially for those companies that produce large-volume and highly cyclical commodity chemicals.

As a result, earnings for many chemical companies plummeted in the third quarter, bringing the average decline for C&EN's sample of 30 firms to a 13% decrease, when compared with third-quarter 1990. Sales for the companies also fell, as did profitability.

Practically the same pattern was repeated for other companies that are major producers of chemical products. Oil firms reported a big earnings plunge in the third quarter, as did diversified manufacturers that include chemicals in their portfolios. Once again, only the pharmaceutical companies recorded good increases on a year-to-year basis.

And once again, the explanation is easy. The U.S. is in the throes of recession. The result is that demand for chemicals and related products is down in many major U.S. industries, including two of the biggest—housing and automobiles.

Although this, of course, does not affect chemicals across the board, it does have a big impact on the major commodity products, especially petrochemicals. And since petrochemicals are such a large part of the in-

Chemical industry leaders for third quarter . . .

Sales				Earnings[a]			Profitability		
Rank 1991		$ Millions	Rank 1990		$ Millions	Rank 1990		Earnings as % of sales	Rank 1990
1	Dow Chemical	$ 4502.0	1	Dow Chemical	$223.0	1	Loctite	13.7%	3
2	Monsanto	2042.0	2	Monsanto	116.0	3	Great Lakes Chemical	12.2	2
3	Union Carbide	1751.0	3	Air Products	58.4	4	Betz Laboratories	11.7	4
4	W. R. Grace	1621.6	4	American Cyanamid	56.3	7	Nalco Chemical	10.0	5
5	American Cyanamid	1118.1	5	Ethyl	55.3	5	Ethyl	8.9	8
6	Air Products	738.4	6	W. R. Grace	49.6	10	Lubrizol	8.1	6
7	Hercules	717.0	7	Rohm & Haas	39.5	9	Air Products	7.9	14
8	Arco Chemical	705.0	9	Great Lakes Chemical	39.2	13	IMC Fertilizer	7.7	9
9	Rohm & Haas	672.1	8	Arco Chemical	35.0	6	Georgia Gulf	7.5	7
10	B. F. Goodrich	649.5	11	Nalco Chemical	34.7	15	Crompton & Knowles	7.3	13

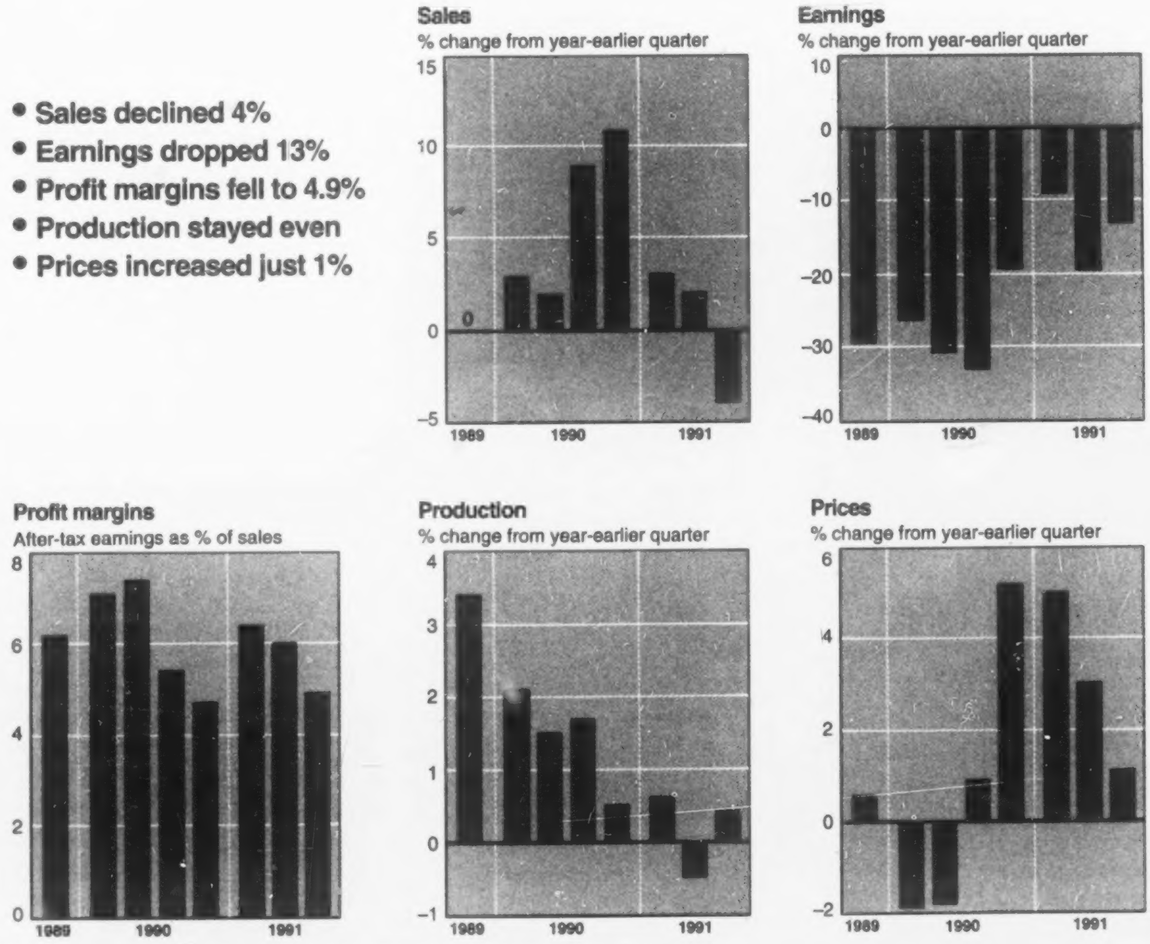
. . . and for first nine months of 1991

Sales				Earnings[a]			Profitability		
Rank 1991		$ Millions	Rank 1990		$ Millions	Rank 1990		Earnings as % of sales	Rank 1990
1	Dow Chemical	$14,244.0	1	Dow Chemical	$821.5	1	Loctite	13.9%	3
2	Monsanto	6,738.0	2	Monsanto	555.0	2	Great Lakes Chemical	12.0	2
3	Union Carbide	5,359.0	3	American Cyanamid	292.9	4	Betz Laboratories	11.4	5
4	W. R. Grace	4,971.9	4	Union Carbide	169.0	3	Nalco Chemical	10.2	5
5	American Cyanamid	3,851.3	5	Air Products	166.9	6	Lubrizol	8.3	8
6	Hercules	2,219.0	6	Ethyl	158.3	8	Ethyl	8.3	9
7	Air Products	2,206.5	7	W. R. Grace	138.0	9	Monsanto	8.2	17
8	Rohm & Haas	2,104.7	8	Rohm & Haas	133.6	7	Crompton & Knowles	8.0	10
9	Arco Chemical	2,090.0	9	Arco Chemical	120.0	5	IMC Fertilizer	8.0	16
10	Ethyl	1,915.1	13	Great Lakes Chemical	117.8	11	American Cyanamid	7.6	15
							Air Products	7.6	13

Note: Based on 30 chemical companies listed on page 12. a After taxes.

Chemical industry 1991 third-quarter results

- Sales declined 4%
- Earnings dropped 13%
- Profit margins fell to 4.9%
- Production stayed even
- Prices increased just 1%



Note: All sales, earnings, and profit margin data are based on 30 chemical companies listed on page 12.

dustry, both in terms of physical volume and dollars, the downturn in these products has enormous effects on the fortunes of the entire industry.

As a result of the declining demand for chemicals, capacity use for the industry fell to a seasonally adjusted 78.8% for the third quarter, according to government data, from an average 81.3% in the same period a year earlier. Overall, much of this drop is due to new chemical plants starting up during the intervening period, but in parts of the industry, it includes decreasing demand leading to declining output at chemical plants.

Overall production for all U.S. chemical plants, according to the Federal Reserve Board, was essentially unchanged in the third quarter when compared with the year-earlier period. However, for industrial organic chemicals, the subcategory that contains basic petrochemicals, output was down an estimated 7%.

Falling product demand, and its resulting lower capacity utilization, naturally led to weakening prices in the third quarter. Again, according to government figures, prices for chemicals and allied products rose just 1.1% in the third quarter from the same period last year—well below general inflation in the U.S.

For some subcategories, the picture was bleaker. Prices for industrial chemicals, which include both basic inorganic and organic products, fell an average of 2.1%, according to government data, whereas prices for the even narrower industrial organic sector dropped 3.2%.

The result was that not only did earnings drop for the period, but sales also declined. For the 28 chemical companies that had reported by press time, earnings dropped an average 13% in the third quarter from last year's third quarter to a total of $983 million. Sales, meanwhile, fell an average 4% to just under $20 million. The result was that profit

In spite of overall earnings drop, only nine chemical companies registered declines

	THIRD-QUARTER 1991						NINE-MONTHS 1991			
	Sales	Earnings[a]	Change from 1990		Profit margin[b]		Sales	Earnings[a]	Change from 1990	
	($ millions)		Sales	Earnings	1991	1990	($ millions)		Sales	Earnings
Air Products	$ 738.4	$ 58.4	−10%	2%	7.9%	7.0%	$ 2,206.5	$ 166.9	−2%	−3%
American Cyanamid	1,118.1	56.3	6	8	5.0	4.9	3,851.3	292.9	12	14
Arco Chemical	705.0	35.0	4	−38	5.0	8.2	2,090.0	120.0	1	−50
Betz Laboratories	170.3	19.9	11	13	11.7	11.5	500.0	57.0	13	15
Cabot	na	na	na	na	na	2.5	na	na	na	na
Crompton & Knowles	115.1	8.4	19	20	7.3	7.3	340.3	27.3	18	20
Dow Chemical	4,502.0	223.0	−8	−21	5.0	5.8	14,244.0	821.5	−3	−26
Ethyl	623.1	55.3	0	−2	8.9	9.0	1,915.1	158.3	4	−4
First Mississippi	139.5	5.3	3	23	3.8	3.2	423.0	7.7	6	20
H. B. Fuller	213.9	8.2	5	27	3.8	3.2	632.4	18.9	7	45
Georgia Gulf	206.4	15.6	−11	−33	7.5	10.0	656.0	49.3	−7	−35
B. F. Goodrich	649.5	20.7	2	−59	3.2	8.0	1,864.2	26.1	0	−74
W. R. Grace	1,621.6	49.6	−3	10	3.1	2.7	4,971.9	138.0	3	7
Great Lakes Chemical	320.5	39.2	20	11	12.2	13.2	985.7	117.8	27	13
Hercules	717.0	34.5	−12	17	4.8	3.6	2,219.0	101.7	−7	9
IMC Fertilizer	258.7	20.0	−3	−13	7.7	8.6	847.4	67.9	−1	7
Imcera	381.3	23.1	1	38	6.1	4.5	1,243.3	84.3	8	40
International Flavors	na	na	na	na	na	16.2	na	na	na	na
Loctite	140.3	19.3	1	10	13.7	12.7	419.7	58.4	2	14
Lubrizol	357.6	28.8	−2	−25	8.1	10.5	1,100.0	91.8	2	−9
Monsanto	2,042.0	116.0	−5	57	5.7	3.5	6,738.0	555.0	−1	15
Morton International	475.0	34.1	5	1	7.2	7.5	1,458.2	108.6	10	5
Nalco Chemical	345.8	34.7	18	6	10.0	11.2	985.0	100.4	14	5
Olin	551.3	15.2	−16	6	2.8	2.2	1,680.7	57.2	−14	−24
Petrolite	81.1	4.0	11	45	4.9	3.8	242.3	10.6	12	6
Quantum Chemical	573.0	−38.1	−8	def	def	def	1,895.7	−58.9	0	def
Rohm & Haas	672.1	39.5	−2	−14	5.9	6.7	2,104.7	133.6	−2	−21
Stepan	106.4	3.8	5	7	3.6	3.5	313.3	8.9	7	−23
Union Carbide	1,751.0	32.0	−10	−61	1.8	4.2	5,359.0	169.0	−7	−44
Witco	420.4	21.2	0	8	5.0	4.7	1,240.0	54.0	2	−6
TOTAL[c]	**$19,996.4**	**$ 982.8**	**−4%**	**−13%**	**4.9%**	**5.4%**	**$62,526.6**	**$3554.7**	**0%**	**−14%**

a After-tax earnings from continuing operations, excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales. c For 28 companies reporting.

margins for the 28 companies averaged 4.9%, down from 5.4% a year earlier.

Although the 13% decline may seem substantial, it still is less than the 18% drop recorded in the second quarter this year and it is a smaller annual decline than in any of the eight previous quarters, except for the first quarter of this year when earnings fell just 8% on a year-to-year basis.

However, on a quarter-to-quarter basis, these chemical companies showed up very badly in the third quarter. Although the third quarter is normally weak, this year's earnings fell 23% between the second and third quarters, and sales dropped 6%.

For the first nine months of this year, combined earnings for the 28 companies totaled $3.55 billion, down 14% from the same period last year. Combined sales for the period remained about the same as a year earlier, at $62.5 billion. The effect on profitability was to lower profit margins to 5.7% in the first nine months of 1991 from 6.6% in the same period a year earlier.

An indication of the effect of commodity chemicals on chemical company earnings is that of the 28 companies that had reported by press time, just nine reported earnings declines for the third quarter. Not included is Quantum, whose loss of $38.1 million in this year's third quarter makes last year's third quarter loss of $1.4 million look almost bearable. And Ethyl's earnings decrease amounted to just 2%. The remaining declines were in the double-digit range—but they were earnings nonetheless, not losses.

Most of these nine companies, and especially those with the largest

NINE-MONTHS 1991		12-MONTHS RUNNING DATA			
Profit margin[b]		Change from 1990		Profit margin[b]	
1991	1990	Sales	Earnings	1991	1990
7.6%	7.7%	1%	10%	8.1%	7.5%
7.6	7.5	9	18	7.0	6.5
5.7	11.6	6	−40	6.6	11.8
11.4	11.1	14	16	11.2	11.0
na	3.3	na	na	na	2.7
8.0	7.9	18	20	7.8	7.7
5.8	7.6	3	−29	5.6	8.1
8.3	9.0	4	−5	8.3	9.2
1.8	1.6	2	−20	1.2	1.5
3.0	2.2	7	38	3.2	2.5
7.5	10.8	−6	−49	7.7	14.3
1.4	5.5	0	−69	1.6	5.3
2.8	2.7	6	2	3.1	3.2
12.0	13.4	27	14	12.1	13.5
4.6	3.9	−4	93	4.2	2.1
8.0	7.4	0	8	8.3	7.6
6.8	5.2	11	52	6.4	4.7
na	17.2	na	na	na	16.3
13.9	12.4	14	16	12.3	12.1
8.3	9.4	8	6	8.4	8.6
8.2	7.1	2	−1	6.3	6.5
7.4	7.8	11	1	7.2	7.9
10.2	11.1	14	6	10.4	11.2
3.4	3.9	−9	−39	2.8	4.2
4.4	4.6	11	1	4.2	4.6
def	0.6	6	def	def	1.2
6.3	7.9	0	−11	6.1	6.9
2.8	3.9	8	−12	2.9	3.5
3.2	5.2	−8	−37	3.4	5.0
4.4	4.7	3	−4	3.9	4.2
5.7%	**6.6%**	**2%**	**−15%**	**5.5%**	**6.6%**

def = deficit. na = not available.

earnings declines, are involved heavily in commodity chemicals. Included are such companies as Dow Chemical with a 21% decline, Arco Chemical with a 38% decline, B. F. Goodrich down 59%, and Union Carbide down 61%.

These nine companies that reported declines are large enough that they accounted for about 44% of total chemical company earnings in the third quarter. However, in the third quarter of 1990, they accounted for 58% of total chemical company earnings, showing the magnitude of their decline.

If these nine companies plus Quantum are eliminated from the sample, however, instead of the 13% decline in earnings averaged for the 28 companies, the remaining 18 chemical companies posted an average 17% increase in earnings.

For Dow, the problem was apparent in its hydrocarbons and energy unit, which includes ethylene. In the third quarter, this segment of the company posted a 23% decline in sales to $442 million and a loss in operating income of $20 million. Carbide's net income for its chemicals and plastics unit fell 86% to $11 million in the quarter.

Earnings for oil companies with large chemical operations dropped 10% in the third quarter to a total of almost $2.64 billion on a 9% sales decline to $81.5 billion. Profit margins slipped slightly to 3.2% in the quarter from 3.3% in the comparable three-month period last year. For the nine months, oil company earnings were up 8% to $10.1 billion, and sales rose 1% to $251 billion. Profitability increased to 4.0% from 3.8% in the first nine months last year.

Oil companies also had their problems with petrochemicals. For Mobil, although total chemical sales were down 6% to $939 million for the quarter, sales of petrochemicals declined 13% to $451 million. This decrease offset a 1% gain in plastics sales and a 63% increase in sales of other chemical products. Chemical earnings at Mobil dropped 55% to $38 million for the quarter.

Texaco's earnings from chemical operations fell 75% in the quarter to just $3 million. Texaco says this is the eighth consecutive quarter that profit margins for commodity chemicals have been depressed because of oversupply conditions throughout the world.

Exxon, however, reported improvement in overall chemical earnings, but the improvement was all overseas. The company posted a 23% increase in chemical earnings to $85 million. However, in the U.S., chemical operations yielded a 23% drop to $65 million.

And Fina (formerly American Petrofina) reported chemical profits were down substantially when compared with last year's third quarter. Ron W. Haddock, the company's president and chief executive officer, said, "Styrene margins were 68% lower than in last year's third quarter due to industry's increased production capacity; lower demand, resulting at least in part from the economic recession; and higher raw material costs."

Diversified companies producing chemicals reported earnings that

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 20 oil and diversified companies, each with more than $200 million in annual chemical sales, plus nine pharmaceutical companies.

To be included in the table of basic chemical producers, a company must have at least 50% of its sales in chemicals. That is why Du Pont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, and agricultural chemicals and specialty derivatives.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

Drug companies continue to be only group showing earnings gains

	THIRD-QUARTER 1991						NINE-MONTHS 1991					
	Sales	Earnings[a]	Change from 1990		Profit margin[b]		Sales	Earnings[a]	Change from 1990		Profit margin[b]	
	($ millions)		Sales	Earnings	1991	1990	($ millions)		Sales	Earnings	1991	1990
OIL AND GAS COMPANIES												
Amoco	$ 7,011.0	$ 365.0	−11%	−4%	5.2%	4.8%	$ 21,091.0	$ 1,163.0	−6%	−7%	5.5%	5.6%
Chevron	10,000.0	231.0	−6	−28	2.3	3.0	30,600.0	1,076.0	6	22	3.5	4.8
Exxon	27,520.0	1115.0	−5	4	4.1	3.7	85,472.0	4,480.0	4	30	5.2	4.2
Fina	837.8	7.7	−21	−71	0.9	2.5	2,477.3	20.2	−11	−81	0.8	3.8
Kerr-McGee	832.2	26.8	−13	−38	3.2	4.5	2,402.0	66.8	−6	−33	2.8	3.9
Mobil	15,025.0	395.0	−8	47	2.6	1.6	46,054.0	1,506.0	2	34	3.3	2.5
Occidental Petroleum	2,330.0	148.0	−14	49	6.4	3.6	7,487.0	376.0	−7	41	5.0	3.3
Phillips Petroleum	2,970.0	56.0	−10	−69	1.9	5.4	9,405.0	275.0	1	−10	2.9	3.3
Sun Co.	2,950.0	0.0	−10	nm	nm	1.0	8,960.0	105.0	−2	−46	1.2	2.1
Texaco	9,356.0	286.0	−15	−25	3.1	3.5	28,567.0	970.0	−1	−9	3.4	3.7
Unocal	2,684.0	9.0	−13	−93	0.3	3.9	8,126.0	89.0	−4	−48	1.1	2.0
TOTAL	**$81,516.0**	**$2639.5**	**−9%**	**−10%**	**3.2%**	**3.3%**	**$250,641.3**	**$10,127.0**	**1%**	**8%**	**4.0%**	**3.8%**
DIVERSIFIED MANUFACTURERS												
Allied-Signal	$ 2,877.0	$ 80.0	−3%	−24%	2.8%	3.5%	$ 8,827.0	$ 227.0	−4%	−36%	2.6%	3.9%
Du Pont	9,426.0	504.0	−5	−5	5.3	5.4	28,930.0	1,643.0	0	−11	5.7	6.4
Eastman Kodak	4,926.0	317.0	3	−55	6.4	14.7	14,337.0	852.0	4	−34	5.9	9.3
Engelhard	571.6	21.2	−35	33	3.7	1.8	1,849.5	65.2	−19	33	3.5	2.1
FMC	967.5	41.7	3	18	4.3	3.8	2,891.5	142.9	5	11	4.9	4.7
3M	3,378.0	296.0	1	−12	8.8	10.1	10,116.0	895.0	4	−12	8.8	10.4
NL Industries	202.4	4.6	−8	−74	2.3	7.9	562.1	(17.2)	−5	def	def	14.0
PPG Industries	1,393.5	68.9	−5	−36	4.9	7.3	4,248.1	169.9	−6	−54	4.0	8.3
Vulcan Materials	289.2	30.2	−6	−28	10.5	13.7	752.7	53.9	−10	−46	7.2	12.0
TOTAL	**$24,031.3**	**$1363.7**	**−3%**	**−28%**	**5.7%**	**7.6%**	**$ 72,513.9**	**$ 4,031.7**	**0%**	**−23%**	**5.6%**	**7.2%**
PHARMACEUTICAL COMPANIES												
Abbott Laboratories	$ 1,653.7	$ 251.6	10%	14%	15.2%	14.7%	$ 4,990.3	$ 774.0	12%	13%	15.5%	15.4%
American Home Products	1,875.8	384.9	8	21	20.5	18.2	5,259.6	1,002.7	2	20	19.1	16.1
Baxter International[c]	2,212.0	156.0	10	16	7.1	6.7	6,531.0	407.0	10	def	6.2	def
Bristol-Myers Squibb	2,757.1	563.4	5	14	20.4	18.9	8,222.2	1,545.5	9	17	18.8	17.5
Eli Lilly	1,341.3	297.5	5	16	22.2	20.0	4,153.1	1,003.6	11	15	24.2	23.3
Merck	2,117.4	552.4	11	19	26.1	24.3	6,288.8	1,591.9	13	19	25.3	24.0
Schering-Plough	887.8	156.0	12	11	17.6	17.6	2,750.0	496.6	9	14	18.1	17.2
Upjohn	831.7	140.2	11	25	16.9	15.0	2,490.4	401.0	12	17	16.1	15.4
Warner Lambert	1,266.5	143.8	7	15	11.4	10.5	3,721.9	437.9	8	15	11.8	11.0
TOTAL	**$14,943.3**	**$2645.9**	**8%**	**17%**	**17.7%**	**16.4%**	**$ 44,407.4**	**$ 7,660.2**	**9%**	**26%**	**17.2%**	**14.9%**

a After-tax earnings from continuing operations, excluding nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales. c Contains nonrecurring item in nine-months 1990. **def** = deficit. **nm** = not meaningful.

were down a much greater 28% in the quarter to $1.36 billion on a sales decline of 3% to $24.0 billion. Profit margins fell to an average 5.7% from 7.6% in third-quarter 1990. For the nine months, earnings were down 23% to $4.03 billion on flat sales of $72.5 billion. Again profit margins fell, this time to 5.6% in the first nine months from 7.2% in the same period last year.

As in the past couple of years, only pharmaceutical companies registered healthy results in the quarter, with earnings up 17% to $2.65 billion on an 8% sales gain to $14.9 billion. Profit margins for the group increased to 17.7% in the third quarter compared with 16.4% in the same period last year. In the first nine months, earnings rose 26% for this group to $7.66 billion on a 9% sales rise to $44.4 billion. The result on profit margins was an increase to 17.2% in the first three quarters this year from 14.9% in the same period in 1990. □

Paper industry changes shake supplier lineup

The pulp and paper industry in Canada—and across all of North America—is at what James Sigurdson calls "a fascinating crossroad." Market, environmental, and other pressures are forcing companies to change the way they operate both their pulp mills and their paper mills.

Traditionally a conservative industry, this simultaneous change has been traumatic for the mills, says Sigurdson, managing director of Law, Sigurdson & Associates, a consulting firm in Toronto. And, he adds, it will mean a new lineup of winners and losers among the companies that supply the mills with chemicals and industrial minerals.

Three major changes are rolling through pulping and bleaching. Kraft bleacheries are changing their bleaching chemicals to meet new environmental regulations. Increasing output of mechanical pulps is making its mark on pulp markets and bleaching chemicals. And the growth of recycled fiber is changing pulp markets.

In papermaking, changes have centered on printing and writing papers, where the move to alkaline papermaking has had a tremendous impact. Alkaline papermaking capacity will increase from 19% of total fine-paper capacity in 1985 to 50% in 1995. This trend already has raised filler levels.

Sigurdson told a recent industrial minerals conference in Toronto that sodium silicate is among the largest winners in the pulping and bleaching arena.

The rising use of mechanical pulping and, to a lesser extent, chemical pulping and papermaking, has given sodium silicate consumption in the mills a major boost. Sodium silicate also is being used in paper deinking and in recycling circuits, where it helps repulping and acts as a collector-processing aid. Sigurdson expects sodium silicate demand to triple, from 23,600 metric tons in 1987 to 68,500 metric tons by 1995. That, says Sigurdson, likely will open up more opportunities for glass-quality silica deposits.

Lime and limestone demand in the pulp and paper sector always has been substantial. And it will get even bigger, says Sigurdson, as mills change to greater chemical recycling. He says lime and limestone consumption in Canadian mills will jump 30% between 1987 and 1995 to 388,100 metric tons.

Soda ash, which is used as an alkali and a replacement for sodium hydroxide in pulping, is another potentially big winner as a result of changes in the pulp mills. Sigurdson says consumption of soda ash in kraft pulping and in paper recycling will grow from 18,000 metric tons in 1987 to 36,500 metric tons by 1995. That's better than a 9% average annual growth rate for a usually slow-growing material.

Increased capacity for kraft pulping is giving a boost to talc's prospects in Canadian pulp mills. Talc consumption in these mills is expected to increase almost 76% between 1987 and 1995 to 36,700 metric tons. The new kraft mills in British Columbia and Alberta are providing most of the thrust.

Paradoxically, sulfur is both a winner and a loser. It is a winner because sulfuric acid consumption in Canadian pulp mills likely will increase 62% or so to 392,400 metric tons in 1995. That will mean more elemental sulfur to make the sulfuric acid.

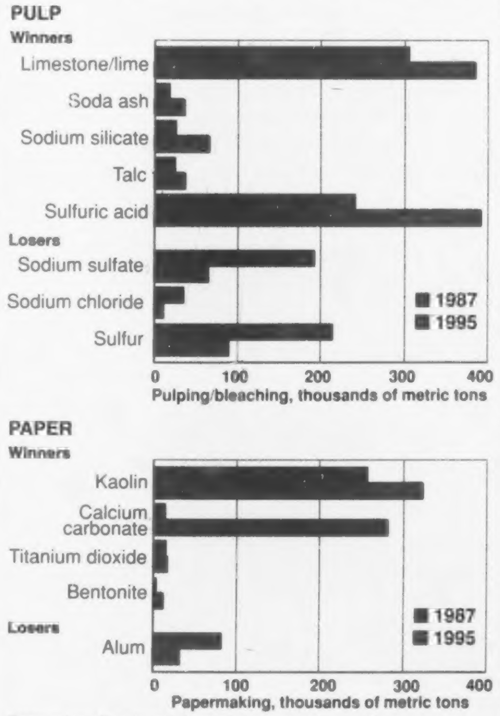
But, in Canadian kraft mills, the use of elemental sulfur itself is dropping dramatically. In part, mills are switching to sulfuric acid for their sulfur values. But they are also using sodium sulfate, which is a by-product from chlorine dioxide generators. In mills across Canada, demand for elemental sulfur will plummet from 211,000 metric tons in 1987 to a miserly 90,000 metric tons in 1995.

Elemental sulfur is not the only loser as a result of changes in Canadian pulping and bleaching. Sodium sulfate has gone from being a prized chemical for obtaining base sulfidity in kraft mills to being a "drug on the market," says Sigurdson. The reason: those chlorine dioxide generators and their sodium sulfate by-product.

Some kraft mills with large chlorine dioxide generators are putting as much as 5000 metric tons of material down the sewer each year, he points out. By recovering this material, demand for sodium sulfate is expected to drop to 66,400 metric tons in 1995. That's 66% lower than its 1987 level.

Generator chemicals also are hitting salt demand at the mills. Sodium chloride use will drop to 30% of 1987 levels, slumping to only 10,000 metric tons by 1995.

In the papermaking end of the pulp and paper industry, the big winner under alkaline conditions is calcium carbonate—both ground and precipitated. Generally, the precipitated material is used as sheet filler, whereas ground material is



Chemical demand in pulp and paper to change dramatically by mid-1990s

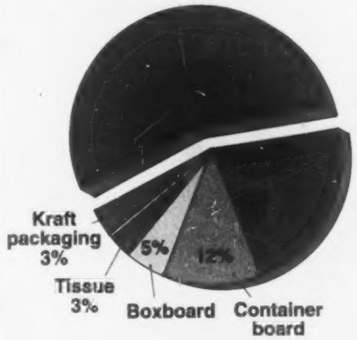
Source: Law, Sigurdson & Associates

used more as a coating pigment. In the Canadian market, both uses are booming, and Sigurdson expects to see demand rise from 12,100 metric tons in 1987 to a whopping 281,700 metric tons in 1995.

Many of the large fine-paper mills in Canada are putting calcium carbonate plants on site at the mill. There are now about 25 precipitated calcium carbonate plants being built or serving mills with "over the fence" filler supply in North America.

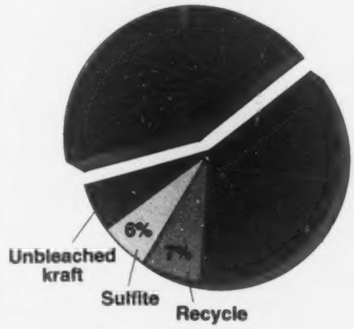
Another big winner is bentonite, a clay used as a filler in paper. As the mills move to alkaline papermaking and as filler levels rise, mills need more sophisticated retention and drainage systems. Although many of the products being used are polyacrylamides, some of these retention systems use bentonite in combination with them. As a result, Sigurdson expects bentonite demand to hit 11,800 metric tons in 1995, up from 2800 metric tons in 1987.

In Canada, newsprint tops paper production . . .



1990 production = 16.5 million metric tons

. . . and mechanical pulp dominates pulp output



1990 production = 23.9 million metric tons

Source: Law, Sigurdson & Associates

Kaolin is under pressure in the Canadian paper filler market. Demand for kaolin will continue to grow, but much more slowly than before. Demand in uncoated sheet mills will decline, as these mills move to alkaline processes and to carbonate fillers. But growth in coated groundwood paper in Canada will offset this decline and will push total kaolin demand up from 259,100 metric tons in 1987 to 320,300 metric tons by the middle of this decade.

Titanium dioxide also will hold its own in the Canadian paper market, despite the loss of some business to carbonate fillers. The call for whiter, brighter paper products will help keep titanium dioxide demand solid through 1995, if not much higher than it was in 1987.

However, the use of alum, or aluminum sulfate, has dropped markedly at newsprint mills, and the switch to the alkaline process has hurt alum demand in fine papers. As a result, says Sigurdson, alum will be a big loser in Canadian paper mills. He estimates that demand will drop about 64% between 1987 and 1995 as a result of the process changes taking place in these mills.

Overall, Sigurdson thinks the Canadian pulp and paper industry will continue to provide a dynamic market for industrial minerals and other chemicals. Producers are expanding their paper product lines. And they are becoming much more sophisticated. This alone spells bigger markets for industrial minerals.

In addition, Sigurdson says the recession plaguing the pulp and paper industry will disappear. And the industry will overcome its problem of overcapacity, emerging stronger and with a high level of productivity.

Raw materials suppliers will find that the Canadian pulp and paper industry will be demanding more sophisticated products. Much of the industry is buying raw materials on a total "cost-in-use" basis, he says. And mill managers now are much more willing to switch products—and even processes—to meet market or environmental requirements.

Earl Anderson

Australian chemical industry battles image

Future development of industry in Australia is the subject of numerous studies and planning efforts by a variety of concerned groups. One prominent study has been conducted by a chemical industry task force for the state of New South Wales. Although restricted primarily to New South Wales, Australia's most populous region, reports from the task force are probably more generally applicable and provide a reasonable outlook for the Australian chemical industry in the near future.

The task force stemmed from a previous investigation commissioned by the New South Wales government that identified a number of industrial and commercial targets for development. Prominent among them was the chemical industry. The task force included industry, government, business, and labor inputs and was chaired by Bruce J. McAllen, head of ICI Australian Operations.

A frequently expounded view is that the chemical industry in Australia is "under siege and faltering." A task force report explicitly notes that the activities of environmental extremists have been concentrated on the chemical industry, probably because it is the most accessible target. To some, the operation of chemical plants is considered antisocial, and there are even advocates for eliminating chemical plants altogether. As a result, some pessimistic observers foresee future deindustrialization.

These are the images that have been created in the popular press in Australia. The facts, however, are quite different from the images, says the task force.

The Australian chemical industry is highly regulated, and most companies are in compliance with regulatory directives. Those that aren't in compliance have been fined or otherwise penalized. The industry is essential to the economic health of New South Wales because of its large payroll and the tax revenues it generates. The products from the industry are essential to the well being of the society and include products for medicine, transportation, materials, and agriculture.

NSF's Chemistry Division Looks for Creative Solutions to Budget Woes

Faced with yet another disappointing funding increase, resourceful division shifts monies among programs to stretch grant support

Pamela S. Zurer, C&EN Washington

The chemistry division of the National Science Foundation is physically situated, like the rest of the agency, in a slightly dilapidated office building in downtown Washington, D.C. But given the pressures on the division, its situation might more aptly be described as between a rock and a hard place.

The division is the source of about one fifth of all federal support for academic research in chemistry, directing about 80% of its resources to individual scientists. Yet its budget hasn't increased in real dollars in years. It turns down many more worthwhile grant proposals than it funds. And many of the applicants who do succeed in winning NSF grants complain they are too small.

"Probably 80% of the proposals we get are worthy of support," says division director Kenneth G. Hancock. "Instead we support only one in three. We support that one at probably only two thirds of what it asks for. And what it asks for is probably artificially trimmed in recognition of reality."

At the same time that the pressure for its limited dollars has been increasing, the division has been stretching to take on more and more responsibility for educating future generations of chemists by vigorously supporting programs for undergraduates and postdoctoral fellows.

"We've taken the position it's appropriate for the chemistry division to be more than just a research division," Hancock says. "We should be a disciplinary division that is focused on coupling research and education."

Up to a month ago, it looked like this year there might be some relief from the pressure. The division was expecting its fiscal 1992 budget to grow to about $112 million, up 10% from the year before. After having to make do since 1987 with small increases that didn't even keep up with inflation, the division's officers knew exactly where they wanted to put the extra money.

"We need an across-the-board increase in the purchasing power of grants," says Hancock. "The American Chemical Society did an analysis that found the average NSF chemistry grant has lost 22% of its purchasing power in the past four to five years."

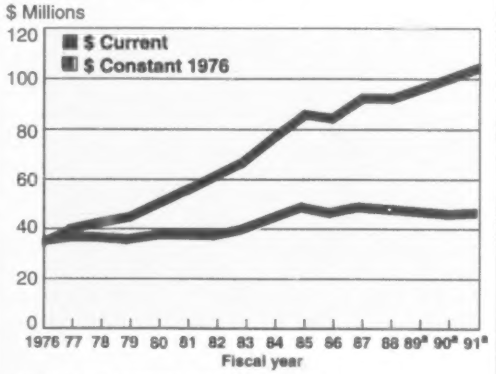
Also, the division wanted to add $3.1 million to fund its share of projects in materials synthesis and processing, a new multidisciplinary initiative. Another $900,000 was to go to programs aimed at women, minorities, and undergraduates.

Last month, however, the hoped-for 10% increase evaporated. When Congress finally completed work on NSF's 1992 budget—well after the Oct. 1 start of the fiscal year—it had given the agency less than it requested for research. Although NSF is still working out exactly how to divide the smaller pie, it now appears likely the chemistry division will get only about a 7% increase to $109 million.

By the time the division's advisory committee met on Oct. 31, Hancock and his coworkers had devised a strategy to cope with the disappointment. By encouraging chemists to take advantage of a new NSF-wide Academic Research Instrumentation (ARI) program, Hancock explained, the division could shift funds out of its own program for shared instruments, where demand of late has been low. That would allow it to put all of its funding increase into the physical, organic, inorganic, and analytical chemistry programs and still have the money for materials initiative and educational programs.

That sort of flexibility in the face of severe constraints has won the division the respect of the chemical community. "One of the things I've been proudest of as a chemist is the inventiveness of this division in trying to devise productive ways to serve science," said advisory committee chairman Larry R. Faulkner, dean of the University of Illinois' College of Liberal Arts & Sciences.

Chemistry division budget has seen no real growth in years



a Includes funds for science and technology centers.
Source: National Science Foundation

At its meeting, the committee voted to back the division's plan for 1992. "The strategy responds to the most pressing problem of the chemical community," Faulkner said. "Institutions are having trouble with matching funds so they are not applying for new instruments now. Eventually the need for instrumentation will resurface. But for 1992 the most pressing problem is the lagging purchasing power of grants."

A few years ago, the advisory committee was more concerned about the number of grants the chemistry division was making than their size. "They told us: 'You are already declining so many high-quality proposals we don't know how you can turn down any more,'" Hancock says.

Therefore, over the past few years the division has maintained the number of grants it supports at about 900 each year. That has meant the average grant size remained for several years in the mid-$80,000s, a figure that includes indirect costs.

"NSF grants are in fact grants-in-aid," Hancock says. "It's never been pretended that they pick up the full costs of a research project. We would if we could. We are trying to make the resources stretch to include as many people and high-quality projects as we can without creating a fleet of three-wheeled buses."

But the situation has deteriorated of late, suggesting some research vehicles are stuck on the highway missing a wheel. The advisory committee now is recommending the division concentrate on beefing up grants. That could mean turning down even more borderline applications—a task chemistry division staff already anguish about.

"The most difficult thing, when you are working to encourage people, is to decline proposals that are worthwhile because of insufficient funds," says Henry N. Blount III, an analytical and surface chemistry program officer.

"We're aware of how much of a toll inflation has taken in research," says Margaret A. Cavanaugh, a program officer in inorganic chemistry. "In each program people are wrestling with grant size as opposed to the number of awardees. What should you do? Make room for new people or increase grant size?"

C&EN staff photos

Cavanaugh, Hancock, Blount, and Rubottom (clockwise from above) regret high-quality proposals that don't get funded, the hard funding choices, the difficulty of saying no

"The hardest part is saying no," says George M. Rubottom, a program officer in organic synthesis. "We say it an awful lot. We try to turn it into a mentoring session to help people do better in the next round."

But sometimes, Hancock points out, there's really no advice to give. "There is nothing wrong with the large majority of proposals. If we had three times as much money we would be delighted to support them."

The division's budget for individual research grants is divided among four disciplinary divisions: organic, inorganic, physical, and analytical and surface chemistry. (Organic is further subdivided into organic synthesis and organic dynamics.) In fiscal 1991, physical chemistry was initially allotted about 30% of the funds, organic about 25%, inorganic about 17%, and analytical/surface chemistry about 13%. The allocation is based on past experience and expectations of future needs.

"The basic principle we try to use is the concept of equal quality," Hancock says. "The projects we fund should be of comparable quality in all of the subfields of chemistry. We don't want to fund mediocre chemistry X and be declining excellent science Y. To a very large degree the incoming proposals, in number and quality, determine where the resources go."

In addition, Hancock withholds a portion of the available money as a reserve. It is distributed later in the year as the pressures on the programs become better known. Some programs get more of the reserve, some none.

The chemistry division has no set deadlines for grant proposals, accepting them anytime during the year. Once received at NSF, staffers decide to which program proposals should be assigned, so that like compete with like. "Most of the time it's fairly clear where a proposal should go," Cavanaugh says. "But chemistry is becoming interdisciplinary. Inorganic, for example has borders with biochemistry and biophysics and materials research in addition to interfaces with inorganic and organic and analytical chemistry."

If a proposal straddles more than one NSF division—say, chemistry and molecular biosciences—it may be reviewed by reviewers from both communities. If successful, it may be jointly funded by both divisions.

After a home has been found for each proposal, the program officer decides who will review it. In the chemistry division, the staff looks for six reviewers who are asked to mail or fax in their evaluation within a month. Before a funding decision is made, the application must have at least three substantive reviews and virtually always has at least four.

"That's the heart of our job," Cavanaugh says. "No matter whether the proposal is successful or not, if we provide the person who wrote it with the best possible evaluation

and feedback that's a real service to the community."

Reviewers and staff judge proposals using four criteria: the proposal's scientific merit; the capability of the principal investigator to do the work; the utility or relevance of the research; and its effect on the scientific infrastructure, such as education and human resources.

"We are deciding among very many excellent proposals," Hancock says. "We think we're better off getting as much input from reviewers as we can. We invite them to comment on everything and then it's up to the program officers to sort out the wheat from the chaff."

Some scientists are uneasy about NSF's recent focus on what it terms infrastructure. They worry that scientific merit is in danger of taking a back seat to other concerns. Hancock says the agency has defined the term very broadly and set itself wide goals.

"Infrastructure includes worrying about the undue concentration of resources in one individual or one institution or one region of the country," he says. "But it also encompasses such issues as the participation of women and minorities and of undergraduate schools as well as doctoral institutions.

"To me it seems it also addresses such issues as scientific talent," he continues. "Do we concentrate on what may be faddish today and ignore something that has potential for tomorrow? Do we worry about paying attention to experiments which are high risk or proposals which challenge established thought and could be very controversial?

"All of those are infrastructure questions. We're saying, 'Don't just take the easy way out and only worry about scientific merit.' But other concerns are never a substitute for scientific merit. We never fund a mediocre proposal just because it's relevant or because it happens to be the only proposal from that state this year."

Once peer reviews are in, the program officers decide which grants get funded and at what level. In chemistry, the program officers normally work in pairs consisting of one permanent staff member and one visiting scientist (rotator) on one-year leave from his or her university.

(About half of the chemistry division staff are visiting scientists. "It brings in people who are absolutely up-to-date in their field and complements the expertise of permanent staff," Hancock says. "And the rotators go back to their universities with first-hand knowledge of how the system works.")

The program officers' recommendation is then reviewed by both deputy director John B. Hunt and Hancock. "In the very large majority of cases there is excellent concurrence on the yes/no decision," Hancock says. "There is some discussion on a small fraction of cases about the level of support. That comes about because we try to keep a balance among the different subfields."

The chemistry division's biggest effort in education is in the NSF-wide Research Experiences for Undergraduates (REU) program. Set up in 1987, its goal is to give undergraduates a taste for research by having them spend the summer working in a lab. The REU program is modeled after the old NSF Undergraduate Research Program (URP), in which many of today's chemists took part during the 1960s and 1970s.

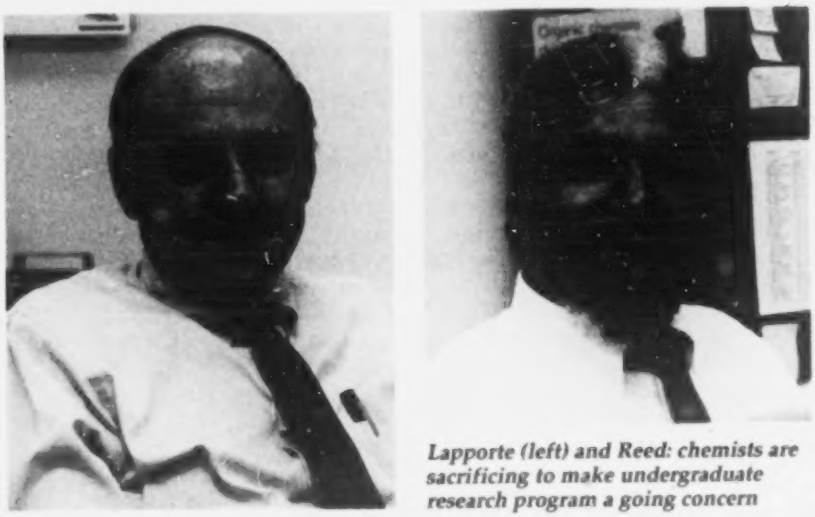
"We really have been leaders in this [REU] program," Hancock says. "That program has grown to $3 million for us over four years when the total growth for the chemistry division has only been about $8 million." The chemistry division is now supporting 57 REU sites that are serving about 600 students a year—a quarter of the total supported by NSF as a whole. Almost half of the participants are women and 15% are underrepresented minorities.

"Chemists think that REU is so important that our advisory committee was willing to sacrifice research grant funding to make it a going concern," Hancock says. "Chemistry is a hands-on science. Chemists learn by doing."

Joseph Reed Jr., the division's coordinator for the REU program, says proposals for participation in REU are intensively screened by a review panel. "The environment is critical. We want the students to feel they are part of the community. Do the faculty want to give students a real research experience? Just relegating them to graduate students or postdocs is not what we want. We are looking for faculty involvement."

The chemistry division also devotes about $1.5 million per year to postdoctoral fellowships in chemistry—a program that is not NSF-wide but originated within the division. New Ph.D.s are supported for one or two years of postdoctoral research and can apply for a leveraged starter grant if they go on to a tenure-track faculty position.

"The program encourages new Ph.D.s to broaden their experience and training," says special projects program officer Seymour J. Lapporte. "Beyond that it encourages



Lapporte (left) and Reed: chemists are sacrificing to make undergraduate research program a going concern

them to go into academic research and teaching."

Applicants for the fellowship must prepare original proposals focusing on the research they hope to pursue after their postdoctoral stint. The program has received between 110 and 160 applications each year and awards between 15 and 20 fellowships—a success rate of about 15%.

This year Lapporte will be managing the chemistry division's share of the new Materials Synthesis and Processing (MSP) initiative. The $25 million program, in which nine NSF divisions will participate, is aimed at encouraging interdisciplinary research on new and existing materials. In this first year, NSF is placing highest priority on electronic and photonic and biomolecular materials, but will also consider proposals addressing structural, magnetic, and superconducting materials.

The new initiative is a successor to the old materials chemistry and chemical processing program, a joint effort of the chemistry, materials science, and chemical and thermal systems divisions that began in 1987. Although the old program was only open to collaborative proposals, the new MSP initiative will also accept proposals from single investigators.

The chemistry division had expected to fund MSP proposals with part of its 1992 budget increase. Now that the increase has turned out to be smaller than expected, Hancock likely will move $3 million out of the divisions' Chemistry Instrumentation Program (CIP).

Last year the division spent about 16% of its budget on research instrumentation. About $10 million came out of the disciplinary programs' budgets to fund dedicated special-purpose instrumentation under individual research grants. Another $5 million or so came from CIP, which is directed by Reed. That program supports large shared instrumentation such as departmental mass spectrometers or computers. The grants pay for two thirds of the cost of the hardware and the university must come up with the rest.

However, the CIP program had been budgeted at $8.1 million for fiscal 1991. The $3 million it didn't spend was kicked back to the disciplinary programs. CIP simply didn't receive enough worthwhile proposals to justify using all its allocated funds, Reed says. "Why spend money on poor proposals?"

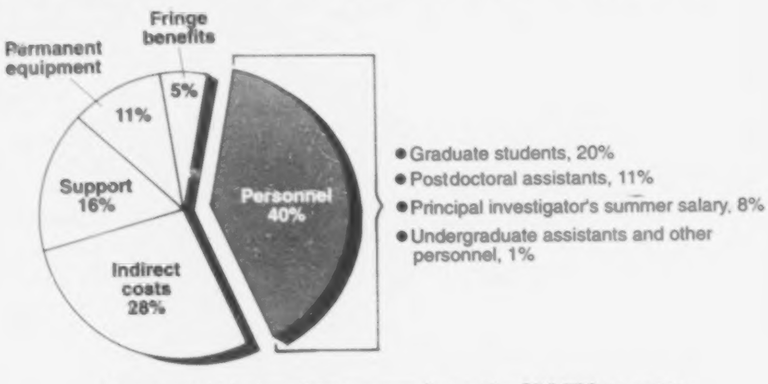
Hancock expects the proposal pressure on CIP to remain depressed for a while, perhaps because research institutions are having such a hard time coming up with the required matching funds. So he now plans to cut CIP's fiscal 1992 allocation to the $5 million level actually spent in 1991 to put the extra into research. The division also will encourage chemists to apply for shared instrumentation through the new NSF ARI program, which will provide half of the funds for instruments costing between $200,000 and $4 million.

That sort of continual juggling to stretch limited resources is typical of the division's staff and reflects their dedication to the chemistry community.

"The role of the program director is to try to support people in their research," Rubottom says. "That's the fun part of the job—the sense of being part of the research enterprise. It's like having a box seat at the World Series."

"When we talk about our responsibilities we're talking about people's livelihood," Hancock says. "If you submit a paper to *JACS* and you don't get it published, there are hundreds of other chemistry journals you can submit it to. But if you don't get a research grant from somewhere, it's hard to stay in business. What we do is life and death. We take it very seriously." ☐

Salaries take biggest chunk of average chemistry grant



Average 1991 chemistry research grant = $94,000 per year

Source: National Science Foundation

Air Pollution and Forest Damage

Regional air pollution is one of the man-made stresses causing gradual and subtle changes over wide, forested areas of the U.S. and Canada

William H. Smith, Yale University

The 1980s will be long remembered as a decade of intense and widespread concern for the vitality and integrity of forest ecosystems. Daily reports of deforestation in the tropics and forest decline in temperate latitudes greatly heightened social consciousness about forest health. As we enter the 1990s, a number of events relative to the interaction of air pollution with forests are occurring rapidly and continuing to heighten the consciousness of society toward forest ecosystems.

Part of what has helped to increase this concern is the 10 years of activity of the National Acid Precipitation Assessment Program (NAPAP). Created by Congress under the Acid Precipitation Act of 1980, NAPAP is mandated to perform a 10-year, multiagency, scientific, technological, and economic study to examine the relationships among energy production, acids and other pollutants resulting from emissions, and the effects of these pollutants on the environment (including forests), the economy, and human health. In 1990, the program issued three detailed "State of Science and Technology" reports that deal specifically with the effects of air pollution on vegetation and forests. This year, it published a summary document on all 27 state-of-science reports it has issued. An integrated assessment of air pollution risks is expected by the end of the year.

In November 1990, joint efforts of Congress and the executive branch culminated in major revisions to the federal Clean Air Act. These revisions, the first in 13 years, have important implications for ecosystem, as well as human, health. Last March, President Bush and Prime Minister Brian Mulroney of Canada signed an environmental accord specifically directed to reduce transboundary acid deposition. And during the past year and a half, the extraordinary changes in the governance of Eastern Europe have made people more aware of the devastating impact that industry and energy generation can have on natural environments, and especially the forests, there.

Almost half of Canada (45%) and one third of the U.S.—about 750 million hectares (or about 1.9 billion acres) altogether—is covered by forests. These forests grow in a full range of conditions from tropical to boreal and contain a large variety of coniferous and deciduous species.

Forests provide many ecological, economic, and cultural benefits to both countries. Besides the obvious forest products—such as lumber, wood fiber, water, and wildlife—they supply less obvious benefits, which include recreation, biological and landscape diversity, shade, wind reduction, sound attenuation, visual attractiveness and screening, water quality, flood and erosion management, soil and nutrient conservation, and storage and detoxification of persistent pollutants.

In addition, U.S. and Canadian forests are sinks for large amounts of carbon dioxide. Nearly all of the U.S. and Canada are in the temperate zone, where forests add 5 to 20 metric tons to their biomass per hectare per

year, which is equivalent to about 2.5 to 10 tons of carbon. Temperate forests rank third behind only tidal zones and rain forests in the amount of carbon they can store in a given year. Therefore, they play an important role in controlling the amount of carbon dioxide in the atmosphere and thus influence global warming.

In the U.S., forests range from pure stands of Douglas fir in the Pacific Northwest, to ponderosa pine in the semiarid West, to mixtures of oaks and southern pine in the South, to the complex multispecies hardwood forests of the Northeast. In Canada, a mixture of coniferous and deciduous species grows in the East, and conifers dominate the West. The softwoods in Canada consist largely of spruce, pine, and fir, whereas hardwoods are primarily poplar, birch, and maple. The forests of these countries receive different amounts of human attention ranging from no management to intensive management, depending, in part, on the products or services people expect from the forests.

Some observers believe the adverse effects of air pollution are important only when they can be measured in economic terms. This leads these observers to conclude that pollution should not be mitigated unless the costs of control are offset by equal or greater benefits. David T. Tingey and colleagues at the Environmental Protection Agency's Environmental Research Laboratory, Corvallis, Ore., argue, however, that "adverse effects" must be broadly viewed when assessing air pollutant stress on ecological systems. I fully agree that all forest products and services, whether or not they have been quantified in economic terms, are important when considering the adverse effects of air pollution.

Fundamentals of forest health

Understanding fundamental principles of forest health is essential for developing an accurate perspective on how regional air pollutants affect complex forest systems. Factors capable of causing injury, disease, and mortality in forests are termed stresses. These may be biotic (living) or abiotic (nonliving), natural or unnatural. Factors recognized to have widespread importance include climatic, pathologic, entomologic, and anthropogenic elements, as well as wildlife, fires, tree age, and competition among trees. Because trees are generally large and long-lived, their health integrates the influences of all stresses that have acted on them. Although the list of forest health problems is very long, disease and premature mortality in most forests remain the exception rather than the rule.

Forests in temperate zones have relatively low biological diversity and are relatively stable. Tree mortality is high in seedlings and early development stages, but medium to low in mature and old trees. Louise M. Tritton of the Department of Agriculture's Forest Service in Burlington, Vt., and Thomas G. Siccama of the School of Forestry & Environmental Studies at Yale University recently provided one of the few regional inventories of the proportion of standing dead trees in northeastern U.S. forests. They documented—over a wide diversity of forest histories, ages, species, and sites—that 5 to 36% of the standing trees are dead.

The significance of various stress factors in temperate zone forests varies greatly with tree age, soil type, aspect, elevation, and climate. For example, white-pine blister rust, which thrives better in cool temperatures, is an important disease in northern Wisconsin and northern New England, but less significant in southern Wisconsin and southern New England.

Management objectives also define the relative importance of specific stress factors. Unlike agriculture, where almost any stress causing a loss in productivity is important, the significance of a particular stress in a forest depends on the goals of the manager. Complete or partial defoliation of hardwoods during a single year caused by foliar pathogens or insects, for example, could cause significant economic loss in a forest being managed as a family campground, whereas a single year of defoliation in this same forest, if it was being managed for wood production or as a wilderness area, would be largely unimportant.

Temperate forest ecosystems, like all other ecosystems, are dynamic and, over time, are characterized by variability. Plant and animal diversity and forest productivity change with the developmental stage of such forests. Both biotic and abiotic stresses play fundamental and natural roles in the regulation of species composition and productivity.

In natural forests, perturbations caused by nonliving and living stress factors may be necessary to maintain maximum diversity and productivity. In temperate latitudes, many forest ecosystems have a natural tendency toward periodic perturbations at intervals of 50 to 200 years. These cycles cause waves of biological diversity and corresponding waves of production of living material. Insect outbreaks, fires, and windstorms—even when they cause massive destruction in the short term—may play beneficial and essential roles in the long term. They regulate tree species competition, succession, productivity, and nutrient cycling. In a sense, a forest at any given time is the result of a life-and-death competition among species, and the stresses that have acted on the forest are partly responsible for shifting and maintaining the balance of competition among species.

In a forest, ambiguous tree disease or decline—that is, decline or disease of uncertain cause—is the rule not the exception. Unambiguous stresses with catastrophic impact do occur, such as the 1938 hurricane in New England, the eruption of Mount St. Helens in 1980, and the 1988 wildland fires in Wyoming and California. Equally unambiguous are wide-area defoliations by tussock moths, eastern and western spruce budworms, and gypsy moths, and wide-area mortality caused by diseases, such as chestnut blight, Dutch elm disease, fusiform rust, and white-pine blister rust.

Although these stresses are dramatic, they are not the norm in forest dynamics. More typically, tree disease, decline, and death result from complex interactions of multiple stresses—and the relative importance of specific stresses is difficult to assess. The impacts of air pollution on forests fall into this ambiguous category.

A special and very important type of ambiguous tree disease is termed dieback/decline. It occurs when a large proportion of the trees of a particular species over an area of many square kilometers show symptoms of stress, unusual and consistent growth decreases, or die. Symptoms include chlorosis (a yellowing or paling of foliage), crown thinning, and dieback. Forest dieback/decline diseases are irregular in distribution and discontinuous, but recurrent, in time.

Dieback/decline is more characteristic of mature forests and generally results from sequential and complex interactions of multiple stress factors. Common nonliving stresses include drought and abnormally low and high temperatures. Living agents of particular importance include defoliating insects, borers and bark beetles, root-infecting fungi, and canker-inducing fungi. Typically, an abiotic stress initiates decline and a biotic one ultimately causes mortality. The nonliving stress is often a climatic one, such as less than normal precipitation.

In the U.S., dieback/decline is now especially important to sugar maple and American beech in portions of the northern hardwood forest (extending north from mid-Pennsylvania). In Quebec, many sugar maple stands are in decline, especially in the region south of the St. Lawrence River. From 1930 to 1960, very widespread decline and mortality of yellow birch occurred throughout New England, New York, and southeastern Canada. An important decline of white ash that was most severe in the Northeast during the 1950s may again be increasing.

Almost a third of U.S. forest acreage is managed intensively

Type	Description	Total size (thousands of hectares)	Management intensity
Unmanaged natural forest	Areas of low tree density and/or slow growth	120,000	None
Managed natural forest	Commerical forest land, recreation, and wilderness areas	190,000	Medium
Suburban forest	Specimen, shade, ornamental trees	80,000	High
Urban forest	Park, street trees	40,000	High
Plantation forest	Row pattern planting with regular spacing	20,000	High
Christmas tree plantation	Short rotation, holiday market	200	High
Forest tree seed orchard	Seed production areas	4	Very high
Forest tree nursery	Seedling production areas	6	Very high
Arboretums	Trees established for study, enjoyment	4	Very high

The most widespread and serious declines over the past several decades in the U.S.'s central hardwood forest (from mid-Pennsylvania south through Virginia and Kentucky) have been associated with scarlet, pin, red, and black oak. The present distribution of oak decline is highly variable, but mortality reaches 20 to 50% in hard hit areas and has been especially severe in the George Washington and Jefferson national forests in Virginia. There is evidence that similar declines occurred earlier in this century in the southern Appalachians. And during this century, wide-area dieback/decline episodes of lesser importance in dogwood, sweetgum, yellow poplar, and magnolia have taken place in the central and southern hardwood forests (south of Virginia and Kentucky).

Conifers have also experienced dieback/declines over wide areas. Important North American exam-

Stress factors cause disease and injury to forest trees

BIOTIC FACTORS

Primary causes of disease[a]

- Fungi
- Bacteria
- Viruses
- Mistletoes
- Nematodes
- Mycoplasma
- Insects
- Mites

Primary causes of injury[b]

- Insects
- Mites
- Rodents
- Mammals
- Birds
- Humans

ABIOTIC FACTORS

Primary causes of disease[a]

- Air pollution
- Drought
- Salt
- Adverse soil chemistry or physical structure
- Nutrient deficiencies or excesses
- Competition

Primary causes of injury[b]

- Wind
- Fire
- Temperature extremes
- Moisture extremes
- Lightning
- Volcanic eruptions
- Landslides
- Avalanches
- Harvesting
- Pesticides
- Ice, snow
- Salt, other chemicals
- Radiation

[a] Disease is defined as abnormal physiology from chronic interaction with stress.
[b] Injury is defined as abnormal physiology from acute interaction with stress.

ples of the past 50 years include Alaska cedar, western white pine, and white spruce in the West; and shortleaf pine, other southern pines, and high-elevation red spruce in the East. These red spruce are currently in decline in some areas.

During the past decade, many forest species in Central Europe have also shown symptoms of decline. In some regions, the impact has been especially dramatic on silver fir, Norway spruce, Scotch pine, European beech, and various oak species. In Germany, the third national survey of forest health, conducted in 1985, found that in 55% of the forested area of the former West Germany, trees showed symptoms of stress on their foliage. The inventory recorded 33% of the symptomatic forests had low damage, 19% medium damage, and 3% heavy damage to tree leaves and needles.

Does air quality affect these declines? Unfortunately, scientific understanding of the interactive and sequential nature of stresses that cause forest decline is far from complete. The literature related to North American and European decline phenomena of the past century reveals as much speculation as evidence about causes, in part because no formally accepted rules of proof for decline diseases exist. Incidents of decline with the most conclusively documented causes have occurred in specific stands or very restricted regions.

The study of dieback/decline phenomena in forests in some ways resembles the study of cancer in humans. Cancer is recognized as a multistage process, and many cancers involve the interactions of multiple stresses. Assessing the specific factors involved in certain cancers and their relative importance with confidence is not possible because of the limits of current toxicology. Likewise, assessing the specific factors involved in wide-area forest decline exceeds the current limited capabilities of forest science.

Air pollutants and forest health

Regional air pollutants of greatest documented or potential adverse influence for forests include trace metals (most importantly heavy metals, such as cadmium, copper, lead, chromium, mercury, nickel, and zinc); acidic deposition (primarily the wet and dry deposition of sulfuric and nitric acids); and oxidants, especially ozone.

The response of trees to air pollution can be measured at both the plant and ecosystem levels. The various tissues and organisms of a specific forest ecosystem have very different thresholds for damage from air pollutants. When exposed to low levels of air pollution, the vegetation and soil function solely as sinks or receptors. At intermediate levels, individual plants or particular species may be subtly harmed through nutrient stress, impaired metabolism, predisposition to insect or microbial damage, or direct induction of disease. Exposure to high levels of air pollutants may induce acute disease or mortality of specific plants.

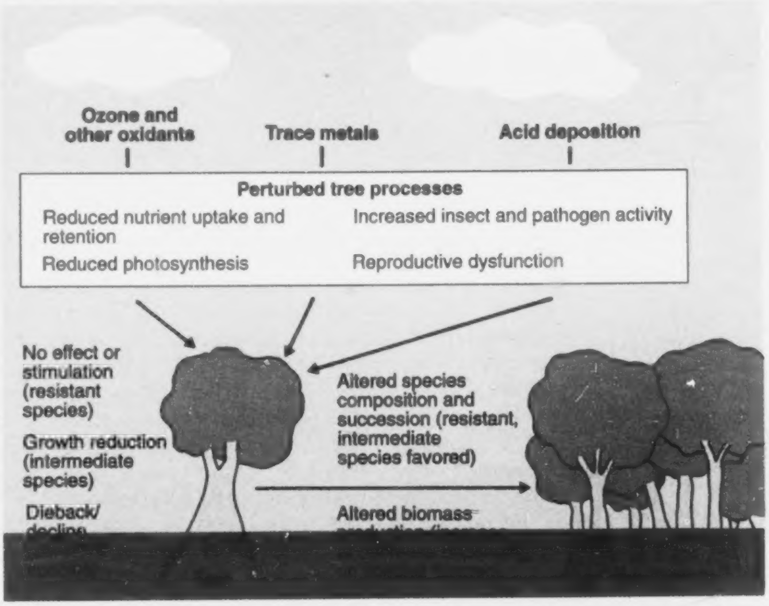
The impact of these interactions on a forest ecosystem is highly variable. When air pollution levels are low, the pollutant is transferred from the atmosphere to various plants and animals and to the soil. The impact on the ecosystem of this transfer could be undetectable and, therefore, innocuous; or it could be stimulatory—for instance, the pollutant could fertilize some of the plants. If an intermediate exposure to the pollutant is harmful to some component of the forest ecosystem, a subtle adverse response may occur, such as reduced productivity or biomass, alterations in species composition or community structure, or increased morbidity. With high exposure, ecosystem impacts may include gross reduction in the number of species, impaired energy flow through the ecosystem, reduced biogeochemical cycling of nutrients, changes in hydrology and erosion, climate alteration, and major impacts on other ecosystems that are affected by the forest.

Heavy metals

Human activities introduce heavy metals into the atmosphere primarily in particulate form. During high-temperature combustion in electric power stations, incinerators, steel mills, and motor vehicles, for example, metal elements and their oxides become volatilized. The elements of high volatility—such as cadmium, chromium, nickel, lead, thallium, and zinc—concentrate on the surfaces of fine airborne particles as they condense. Small particles with diameters of 1 µm or less are efficient collectors of heavy metals because of their large surface-to-volume ratios.

Preferential association of heavy metals with small particles is significant not only because these particles may escape emissions control, but also because they have long atmospheric residence times and, therefore, can be carried long distances. Depending on climatic conditions and topography, fine particles may remain airborne for days or weeks and be transported 60 to 600 or more miles from their source. Ecosystems downwind

Trees, forest ecosystems respond in complex ways to stresses from regional air pollution


Ozone and other oxidants
Trace metals
Acid deposition
Perturbed tree processes
Reduced nutrient uptake and retention
Increased insect and pathogen activity
Reduced photosynthesis
Reproductive dysfunction
No effect or stimulation (resistant species)
Growth reduction (intermediate species)
Dieback/
Altered species composition and succession (resistant, intermediate species favored)
Altered biomass

Ozone and other oxidants, trace metals, and acid deposition from the atmosphere may affect trees and forests in a variety of ways. In sensitive species, certain pollutants may reduce nutrient uptake and retention, reduce photosynthesis, cause reproductive dysfunction, and increase the activity of insects and pathogens that harm trees.

The net result is that resistant species of trees may not be affected at all or may actually be stimulated because the trees they compete with have been harmed by the pollutants. Intermediate tree species, those that are somewhat sensitive to the pollutants, may experience growth reductions, but may show no other obvious effects, and sensitive tree species may show decline and dieback.

At the ecosystem level, the pollutants may cause altered species composition and succession because the resistant and intermediate tree species may be favored, while the sensitive species decline and die. Also, the pollutants may alter the net production of biomass. If the species that are favored by the air pollution usually tend to grow faster than the sensitive species, biomass production could actually be enhanced. If, on the other hand, the favored species grow relatively slowly, biomass production may be decreased

from major power-generating, industrial, or urban complexes receive both wet and dry atmospheric deposition that contains accumulated metals from multiple sources. Most fine particles and elements such as cadmium and lead are removed from the atmosphere with rain, snow, and fog, whereas most large particles and elements such as iron and manganese are deposited between precipitation events.

Extensive evidence indicates that heavy metals deposited from the atmosphere to forests accumulate either in the forest floor (the richly organic layer on top) or in the upper soil horizons (the uppermost soil layers under the forest floor). Because this accumulation is commonly in the part of the soil where the activity of roots and soil organisms is greatest, it has the potential to be toxic to roots and soil organisms and to interfere with nutrient cycling.

All the heavy metals, regardless of whether they are biologically essential, can be directly toxic to trees at some high levels of exposure. Only a few, however, have been documented to cause direct plant toxicity in actual field situations. Toxicity from copper, nickel, and zinc has occurred frequently, whereas toxicity from cadmium, cobalt, and lead has been seen only under unusual conditions. Even at high doses, chromium, silver, and tin have not been toxic in field situations. Trees have shown direct and acute heavy-metal toxicities only in the immediate vicinity of point sources.

In contrast, the lower exposures from heavy metals associated with regional deposition have the potential to interfere with nutrient-cycling processes over the long term. The high productivity of forest ecosystems is achieved and maintained through efficient nutrient cycling. For most forests, the elements required to maintain productivity cannot be sustained from annual precipitation and mineral substrates alone. The release of nutrients from the decomposition of organic material is also required.

Many hypotheses attempt to explain how heavy metals in regional deposition interact with nutrient cycling. Some of the most important are:

- Heavy-metal contamination of soil may interfere with the ability of soil biota to decompose organic matter in the forest floor. Heavy metals may bind with colloidal organic matter in the soil and increase its resistance to decomposition or directly harm or kill microorganisms or arthropods that are important for decomposition.
- A large number of soil enzymes—including free extracellular enzymes and enzymes bound to inert soil components, as well as active enzymes within dead cells and others associated with abiotic cell fragments—participate in important extracellular forest soil processes. By complexing the substrate, by combining with the active group of the enzyme, or by reacting with the enzyme-substrate complex, heavy-metal ions inhibit the reactions of at least 10 of these enzymes.
- Heavy metals may also reduce microbial processes in forest soils. Many studies of large metal-emitting point sources have shown that cadmium, copper, mer-

cury, nickel, lead, and zinc reduce the rates of microbial metabolism in soil. And under experimental conditions, cadmium, chromium, iron, lead, mercury, nickel, silver, and tin reduce nitrification, an important microbial process in both forest and agricultural soils.

- Forests frequently flourish in regions where the supply of soil nutrients is low, marginal, or poor. Forest ecosystems have evolved ways of conserving nutrients and maintaining tight control over nutrient cycling. In addition, trees have evolved critically significant symbiotic relationships with soil fungi and bacteria that enhance nutrient supply and uptake. Many heavy metals—including cadmium, copper, nickel, and zinc—adversely affect fungi and bacteria such as actinomycetes, which serve as important forest tree symbionts.

Heavy-metal stress in forests, however, depends on both the concentration of metals in the soil and their biological availability. Heavy metals that cannot be readily exchanged from soil binding sites or are not in solution are unavailable for root or microbial uptake.

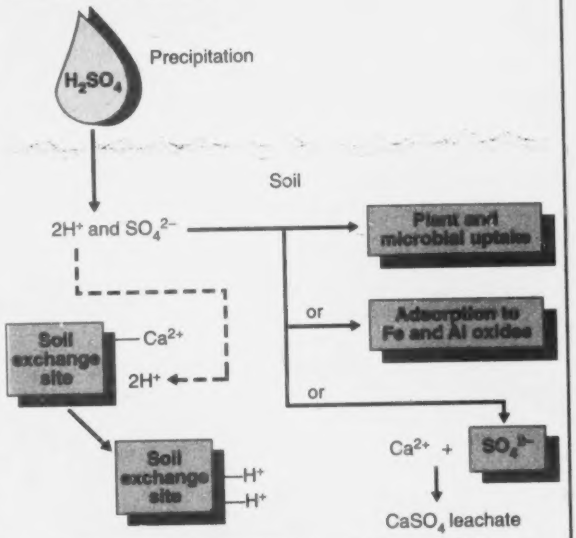
A number of processes make more than 90% of certain heavy metals deposited from the atmosphere biologically unavailable. They are adsorbed or chelated by organic acids, such as humic and fulvic acids; hydrous oxides of aluminum, iron, or manganese; and clays. Soluble cadmium, copper, and zinc may be chelated in excess of 99%. Heavy metals also form complexes with soluble low-molecular-weight compounds or precipitate as inorganic compounds of low solubility, such as oxides, phosphates, or sulfates. For example, William W. McFee, soil scientist at Purdue University, found that lead in a forest soil in northwestern Indiana is present in the following forms: bound to organic matter, 43%; bound to ferromanganese hydrous oxides, 39%; as insoluble precipitates, 10%; and biologically available (exchangeable), 8%. I hypothesize that the lead composition in many forest soils in the Northeast is similar.

Adsorption, chelation, and precipitation are strongly regulated by soil pH. As pH decreases and soils become more acid, heavy metals generally become more available for biological uptake, and concentrations that would not ordinarily be damaging may become so if the pH is low enough. Forest soils generally become more acid as they mature. However, especially in soils with a pH between 5 and 7, acid deposition from the atmosphere can increase the natural acidification process. Such acidification may make the heavy metals in the forest floor more available biologically.

In addition, the soil within about 2 mm of active roots—termed the rhizosphere—may also transform heavy metals from unavailable to available forms. Typically, rhizosphere soil has lower pH, lower water availability, lower osmotic potential, lower redox potential, and higher bulk density than soil away from roots. The rhizosphere processes of pH regulation, protonation, solubilization, reduction, and complexation may all transform unavailable metals to available ones. The pH of the rhizosphere and the availability of organic acids and phosphates may be particularly important in lead uptake.

Organic acids in the rhizosphere capable of complexing copper and zinc may be important in uptake of these metals by the roots. Reduction of manganese to the divalent form may allow greater uptake of this heavy metal. Complexing agents and the reduced pH in the rhizosphere may facilitate cadmium uptake. If rhizosphere processes are changed by acid deposition or oxidants from the atmosphere, the availability and uptake of heavy metals could be enhanced.

Sulfuric acid in precipitation leaches nutrients from soil



When sulfuric acid is deposited in soil by precipitation, nutrient cations can be leached from the rooting zone. Hydrogen ions from the acid may displace nutrient cations, such as Ca^{2+}, held on the negative faces of particles of clay or organic matter—called soil exchange sites—because the hydrogen ions have a higher propensity than calcium ions for attachment to the negative exchange sites. At the same time, the sulfate ion in the acid can follow three alternative pathways. It can be taken up as an essential nutrient by plants or soil microbes, it can be adsorbed to iron or aluminum oxides, or it can combine with the Ca^{2+} that is displaced by the hydrogen ion, and $CaSO_4$ can then leach from the rooting zone. If a sufficient amount of Ca^{2+} is not resupplied by decomposition of organic matter or soil weathering, forest trees may suffer from nutrient stress

Acid deposition

The oxidation of sulfur dioxide and nitrogen oxide emissions in the atmosphere ultimately produces sulfuric and nitric acids, which are deposited on the downwind landscape by both precipitation and dry processes. Sulfur dioxide is produced, among other ways, in the combustion of fossil fuels in coal-fired power plants and in the smelting of sulfur-rich ores. High-temperature combustion forms nitrogen oxides from nitrogen and oxygen: An important source is motor vehicle engines. Unless there is an unusual natural source of acidity, regional precipitation means of pH 5 or less are

Hypotheses propose effects of acid deposition on forest health

Over the past decade, a large number of hypotheses have been proposed to explain how acid deposition may interact with forest health. Most of them have focused on the increased levels of hydrogen, sulfate, and nitrate ions delivered through wet or dry deposition processes. The hypothesis that acid deposition leaches nutrients from soil horizons where roots are active and the proposal that acid deposition increases the biological availability of soil aluminum are receiving the most attention. But several other hypotheses form the basis of active study and experimentation. Some of these are listed here.

- Deposition adversely affects one or more processes of tree reproduction or seedling physiology.
- Deposition inhibits critical tree metabolic processes, such as photosynthesis, respiration, water uptake, or evapotranspiration.
- Deposition alters the allocation of carbon in trees, causing less of it to be stored or used for growth and more of it to be used for respiration and repair processes. Or acid deposition may result in an abnormal distribution of carbon between above-ground and below-ground tissues.
- Deposition increases or decreases microbial symbiotic relationships, such as those of mycorrhizal fungi and nitrogen-fixing bacteria.
- Deposition increases or decreases the activity of microbial pathogens.
- Increased deposition of nitrate and sulfate alters the dynamics of the nitrogen-sulfur cycle, including fertilization. Such disruption is particularly important because forest growth is commonly restricted by the availability of nitrogen.
- Deposition increases or decreases the activity of insect pests.
- Deposition increases or decreases the influence of abiotic stresses, such as temperature, moisture, and high winds.
- Increased input of hydrogen ions to the soil increases weathering rates for soil minerals and alters the availability of tree nutrient cations.
- Tree nutrient cations are leached from foliage tissues by precipitation that passes through the canopy.

generally the result of large anthropogenic emissions of sulfur and nitrogen oxides.

NAPAP is providing substantial details on the patterns of acid deposition in its "State of Science and Technology" reports. Its most complete monitoring results are for wet acid deposition, derived from six major networks that have been operating in North America for at least six years. Information for dry deposition, unfortunately, is much less complete because only two networks, using different procedures, have been monitoring it for only a few years.

The maximum deposition of sulfate and nitrate in precipitation occurs in the northeastern U.S. and southeastern Canada. The deposition locations have remained stable over the past 10 years. Currently, the mean annual pH of precipitation in the northeastern U.S. and in adjacent portions of Canada (also in North and Central Europe) is in the pH range of 3 to 5.5. Individual storms have been recorded with pH values between 2 and 3.

NAPAP's Mountain Cloud Chemistry Program, which ran five monitoring sites in the U.S., has characterized the chemistry of montane precipitation, which largely consists of cloud water (fog) that deposits on trees. Concentrations of H^+, SO_4^{2-}, NO_3^-, and NH_4^+ are 5 to 20 times higher in high-elevation cloud water than in nearby low-elevation precipitation, and cloud-water concentrations of SO_4^{2-} and NO_3^- at high elevations in the eastern U.S. are significantly greater than those in the western U.S. Therefore, the forests located above about 3000 feet along the Appalachian Mountain chain receive high doses of H^+, SO_4^{2-}, NO_3^-, and NH_4^+.

A large number of hypotheses about how acid deposition could affect forest health focus primarily on the greater than normal input of H^+, SO_4^{2-}, and NO_3^- ions delivered through wet or dry deposition processes. One that is receiving a great deal of attention now suggests that trees' nutrient cations are leached from soil horizons, where roots are actively taking up nutrients, to less active soil regions. Another proposes that acid deposition results in increased concentrations of biologically available soil aluminum. This causes roots to take up smaller quantities of nutrient cations or harms or kills fine roots or soil organisms.

To grow normally, trees require adequate supplies of 16 elements. Several of these—notably calcium, magnesium, and potassium—are taken up by tree roots as cations from aqueous solution in the soil. If this soil solution becomes depleted in nutrient cations, trees may be subject to nutrient deficiencies and, in turn, predisposed to additional damage from other stresses.

Nutrient leaching in soils requires additional cations to displace nutrient cations from soil exchange sites and mobile anions to combine with displaced cations for movement. The deposition of strong mineral acids from the atmosphere provides displacement cations in the form of hydrogen ions and mobile anions in the form of sulfate and nitrate ions. In most forest soils, rapid biological uptake may immobilize the nitrate anion, because most forests are nitrogen-limited. Similarly, sulfate anions may be immobilized in weathered soils by adsorption to free iron and aluminum oxides. In other soils, however, especially those low in free iron or aluminum oxides or high in organic matter (which appears to block sulfate absorption sites), sulfate may combine readily with nutrient cations and leach them beyond the rooting zone.

Field evidence of leaching induced by acid deposition comes from diverse forest ecosystems subject to excessive inputs of atmospheric acid and located in regions where the soils are vulnerable to anion migration. A. V. Mollitor and Dudley J. Raynal of the State University of New York, Syracuse, have provided evidence from northern hardwood and conifer stands near Newcomb in the Adirondack region of New York State; Christopher S. Cronan, University of Maine, Orono, has obtained data from the subalpine conifer forests of Mount Moosilauke, N.H.; P. W. Hazlett and N. W. Foster, Great Lakes Forestry Centre, Forestry Canada, have provided evidence from the northern hardwood forest near Sault Ste. Marie, Ontario; and E. D. Schulze, Lehrstuhl Pflanzenökologie, Universität Bayreuth, Germany, has supplied information from the conifer forests of the Fichtelgebirge Mountain region in northeast Bavaria.

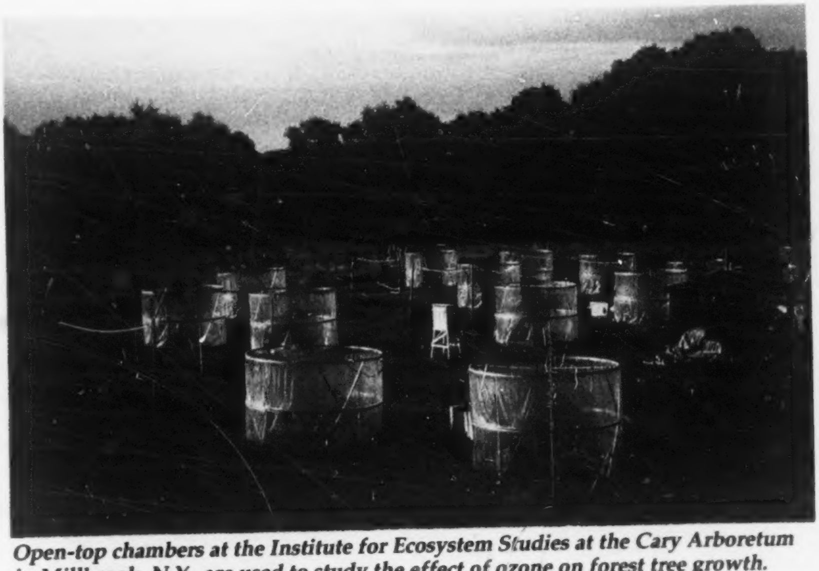
Aluminum, the third most abundant element in Earth's crust, occurs primarily in aluminosilicate minerals, most commonly as feldspars in metamorphic and igneous rocks and as clay minerals in weathered soils. Despite high concentrations of total aluminum in forest soils, aluminum does not usually interfere with nutrient uptake or cause biological toxicity, because it is tightly bound or is in insoluble form. However, when strong mineral acids are added to forest soils, they may mobilize aluminum by dissolving aluminum-containing minerals. They can also remobilize aluminum previously held on soil exchange sites or precipitated within the soil as the soil developed. If soil solutions become enriched in dissolved aluminum, principally as free ions (Al^{3+}) or as the monomeric hydroxides, $AlOH^{2+}$, $Al(OH)_2{}^+$, $Al(OH)_4{}^-$, the risks of aluminum interfering with nutrient cation uptake and of directly killing or harming roots and microbes is increased.

Walter C. Shortle and Kevin T. Smith of the USDA Forest Service in Durham, N.H., suggest that aluminum-induced calcium deficiency is important in the health and productivity of red spruce in the northeastern U.S. They collected tree cores, fine root samples, and soil samples at eight sites throughout northern New England. From their analyses of the cores, they found that calcium is incorporated at a constant rate per unit of wood volume throughout the life of trees and that demand for calcium increases as tree size increases. From chemical analyses of soil, they found that soil acidity levels at all the locations they tested were high enough to allow aluminum to exist in soluble forms in soil solutions. Their analyses of fine root samples found more aluminum than calcium at most sites. Shortle and Smith conclude, as have others, that when aluminum is more prevalent than calcium in the roots and other internal tissues of the tree, calcium is restricted because of competition between these cations for binding sites in tree root interiors. Reduced calcium uptake ultimately suppresses tree growth and may predispose trees to insect and disease attack.

A large integrated project called Aluminum in the Biosphere, sponsored by the Electric Power Research Institute (EPRI), Palo Alto, Calif., measured inorganic aluminum concentrations in many forest soils. In general, the highest available aluminum concentrations are associated with mineral (as opposed to organic) soil layers, where fewer than 10 to 15% of the soil exchange sites are occupied by nutrient cations, soil pH is less than 4.9, and the level of sulfate in the soil solution is greater than 80 micromoles per L.

The highest concentration of aluminum in the soil solution found in North America by the EPRI survey—about 1500 µg per L—was at the town of Big Moose in the Adirondack region of New York. The highest aluminum concentration overall was in the Sölling region, northeast of Bonn, in north central Germany, which had four times the concentration recorded at Big Moose. Available aluminum is directly toxic to trees at sufficient concentrations; specific thresholds vary by species. Its direct toxic effects in root tissues include reduced cell division resulting from aluminum binding to DNA, reduced root growth caused by inhibition of cell elongation, and destruction of epidermal and cortical cells.

The evidence generated by NAPAP and other integrated studies does not provide conclusive evidence that acid deposition has caused a general decline of forest health. However, NAPAP's report on changes in forest health and productivity does not rule out acid deposition "as a potential cause of future ... forest nutrition problems through effects on element cycling." Experimental evidence indicates that acid deposition and associated pollutants may make red spruce less resistant to winter injury and may have contributed to the dieback and mortality of red spruce at high elevations in the northern Appalachians, the report concludes.

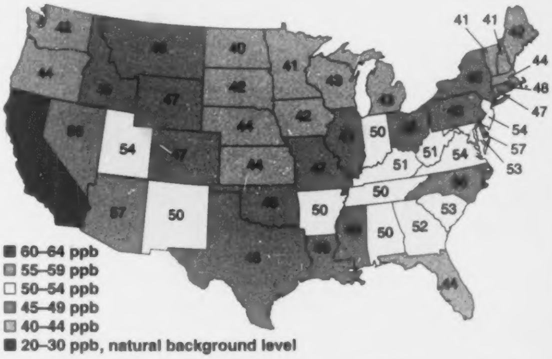


Open-top chambers at the Institute for Ecosystem Studies at the Cary Arboretum in Millbrook, N.Y., are used to study the effect of ozone on forest tree growth. Saplings are grown inside the chambers, which consist of lightweight metal frames covered with plastic film. About 60 cubic meters of air per minute enters the chambers through a manifold in the lower section. The air entering the "control" chamber passes through particulate and charcoal filters to remove ozone and other contaminants. In the other chambers, different levels of ozone are achieved, either by adding ozone to the ambient air or by using various degrees of partial filtration to remove some of the ozone from ambient air

Oxidants

In sunlight, nitrogen dioxide dissociates in the troposphere (the portion of the atmosphere that extends outward about 7 to 10 miles from Earth's surface) and forms equal numbers of nitric oxide molecules and oxygen atoms. The oxygen atoms rapidly combine with molecular oxygen to form ozone. This ozone then reacts with nitric oxide, on a one-to-one basis, to re-form nitrogen dioxide. The steady-state concentration of ozone that is produced by this cycle is small. When hydrocarbons (from incomplete combustion in motor vehicles, for example), aldehydes, or other reactive atmospheric constituents are present, however, they form peroxy radicals that oxidize the nitric oxide back to nitrogen dioxide. With reduced nitric oxide available to react with ozone, the latter may accumulate to relatively high concentrations.

During the growing season, maximum tropospheric ozone levels are above natural background



Numbers represent the maximum seven-hour (9 AM to 4 PM) ozone concentrations in rural areas averaged by state from April to September in 1985–87. Ozone levels are highest on the West Coast and on the East Coast south of Pennsylvania. In all parts of the U.S., the concentrations are enough above the natural background level—20 to 30 ppb—to cause growth reductions in some vegetation. For some states where rural ozone is not monitored, a statistical strategy was used to extrapolate ozone measurements from areas where measurements are made to areas where none are made

Source: National Acid Precipitation Assessment Program

Numerous tropospheric oxidants, such as peroxyacetyl nitrate, nitric acid, and hydrogen peroxide, are toxic to vegetation. Ozone, however, is judged to be the most important atmospheric oxidant because of its elevated levels over vast regions of the U.S. and Canada during the growing season and its demonstrated importance for agricultural crops and forest tree health.

Because ozone can survive at significant concentrations for more than one day of transport, urban plumes are the major contributors to elevated tropospheric ozone concentrations at nonurban locations. According to EPA measurements, more than 100 urban areas in the U.S failed to meet the ambient air quality standard for ozone (120 ppb for daily maximum one-hour average, not to be exceeded more than once per year) during the late 1980s. Large areas of agricultural and forested land throughout the U.S. are exposed to ozone levels above the natural background level, which is 20 to 30 ppb. Ambient air over vast portions of eastern North America has an average ozone level of 50 to 70 ppb on clear summer days, with frequent peak concentrations of 80 to 110 ppb.

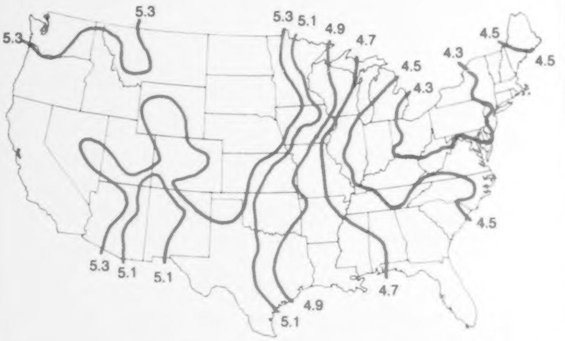
During the past decade, a number of organizations—including EPA through its National Dry Deposition Network and Storage & Retrieval of Aerometric Data programs, EPRI, the Tennessee Valley Authority, and the National Park Service—have monitored rural ozone. Allen S. Lefohn of A.S.L. & Associates, Helena, Mont., and John E. Pinkerton, National Council of the Paper Industry for Air & Stream Improvement, New York, have systematically reviewed rural ozone patterns in forested areas of the U.S. They conclude that elevated ozone concentrations can occur over very wide forested areas, with generally lower frequency in the Pacific Northwest, Upper Great Lakes, and northern New England and New York, and generally higher frequency in the Ohio River Valley and portions of Virginia, North Carolina, South Carolina, Georgia, Alabama, and Tennessee. Additional monitoring performed by states finds high ozone levels in southern New England, the mid-Atlantic states, and southern California.

Unlike heavy metals and acid deposition, whose adverse effects on forest ecosystems are generally long-term and caused by persistent accumulation or gradual process modification, ozone, a very reactive and highly unstable pollutant, interacts very rapidly with trees. For this reason, short-term, high-level ozone exposures are particularly important. But long-term, low exposures are also significant for more subtle adverse effects on plant health, such as yield reductions.

The specific stresses imposed on trees by ozone are extremely varied. The key hypotheses for ozone's adverse impacts on tree health are similar to those for acid deposition. Ozone influences tree reproductive processes, alters (both stimulates and restricts) insect and microbial pathogens of trees, and, at sufficient doses, destroys foliage and fine root tissues. By far, however, ozone affects forest tree metabolism most significantly by interfering with carbon dynamics, including photosynthesis, respiration, and carbon allocation.

Photosynthesis, the most fundamental metabolic process of trees, is the primary determinant of forest growth and biomass accumulation. In mature trees, net photosynthesis frequently takes up from 10 to 200 mg of carbon dioxide per g of dry weight per day. This extremely variable photosynthetic rate is influenced by genetic differences, season of the year, time of day, foliage position within the crown of the tree, age of foliage, solar radiation, climate, and soil factors. Unfortunately, air quality, particularly the ozone level, must also be added to this list. Evidence that ozone influences tree photosynthesis comes from a wide variety of sources ranging from studies of seedlings to large trees

Mean precipitation pH is below 5 east of Mississippi River, above 5 west of it



The pH isopleths represent annual mean hydrogen ion concentrations expressed as pH and adjusted for the weight of precipitation in 1990. Levels below 5 east of the Mississippi River generally are the result of man-made emissions of sulfur and nitrogen oxides. A large number of coal-burning power plants producing huge quantities of sulfur dioxide in the Ohio River Valley cause the pH of precipitation to be especially low in that region and downwind from it

Source: National Atmospheric Deposition Program in the Natural Resource Ecology Laboratory at Colorado State University, Fort Collins, Colo.

and from experiments on trees growing in both controlled and natural environments.

Some of the most interesting and powerful evidence for ozone-induced alteration in carbon dynamics comes from studies employing "open-top chambers." These allow trees to be exposed to known levels of ozone in field (natural) environments. The chambers are cylinders or rectangles about 2.4 meters in diameter and 2.4 meters high constructed of lightweight metal frames covered with clear plastic film. They are equipped with blowers to introduce about 60 cubic meters of air per minute through a manifold surrounding the lower part of the chamber. The air entering "control" chambers passes through both particulate and charcoal filters. Nonfiltered chambers permit the use of ambient pollutants as a baseline for measuring the effect of additional exposures, which are obtained either by adding pollutants or by partial filtration to reduce the ambient pollution level.

Over the past decade, many investigators have employed field chambers to study the influence of ozone on both hardwood (oak, maple, poplar) and softwood (eastern white pine, ponderosa pine, southeastern pine) tree species. In most cases, they find ozone-induced changes in carbon dynamics lead to declines in growth or yield. In many experiments, these declines occurred in the absence of any visible symptoms of stress.

The National Crop Loss Assessment Program, a multiagency federal research effort, has found yield losses in many agricultural crops grown in areas where the seven-hour mean for ozone is 40 ppb during the growing season. Results for selected species of woody plants suggest forest trees may also grow less at the exposures that adversely affect agricultural species.

Peter B. Reich of the Boyce Thompson Institute for Plant Research in Ithaca, N.Y., reviewed the impact of ozone on plant photosynthesis and productivity. At low ozone levels (about 50 ppb), evidence from agricultural crops, hardwood trees, and conifers suggests that net photosynthesis and growth are reduced linearly as ozone uptake increases, he says. Agricultural crops are more sensitive than hardwoods, which in turn are more sensitive than conifers. Reich believes these differences in sensitivity result from several factors: Conifers generally take up less pollutant than crop species and require longer exposure to ozone to receive a comparable dose; conifer foliage is less productive per unit time than crop foliage; and conifer needles have a higher capacity to resist stresses, such as low supplies of nutrients or stresses from insects or microbes, than crop foliage. He thinks hardwoods lie between crop species and conifers in these properties.

Many studies suggest that photosynthesis and growth in agricultural crops decline significantly following one to two weeks of ozone at levels that are common in a typical growing season (50 to 70 ppb). Hardwoods show similar decreases after several additional weeks of elevated ozone concentrations. Effects for them begin when the integrated exposure (concentration × time) above background reaches about 10 to 20 ppm-hours. To show effects, conifers may need several months of elevated ozone concentrations resulting in integrated exposures of about 25 to 100 ppm-hours.

In addition to photosynthesis, the allocation and utilization of carbon within a plant is a critical regulator of plant health. Trees allocate carbon to a variety of processes including growth, respiration (energy generation for growth and tissue repair), metabolism, reproduction, and defensive chemicals to reduce insect attack or microbial infection. Exposure to ozone may influence this carbon allocation. Although all evidence is not consistent, several studies suggest that ozone exposure reduces the movement of carbon to roots. In trees, between 15 and 50% of the carbon fixed through photosynthesis is needed to produce, maintain, and replace fine root systems. A reduction in root growth resulting from a reduced supply of carbon could increase the risk of drought stress and could also exacerbate nutrient deficiencies.

Furthermore, a number of studies indicate that more carbon is allocated to respiration following ozone exposure. More carbon to respiration means less carbon is available to be stored as woody tissue. Similarly, reduced carbon allocation to the synthesis of defensive chemicals could allow more insects and pathogens to harm the tree.

I agree with Reich and his colleagues that the ambient concentrations of ozone that are common over vast areas of farm and forest land throughout the U.S. and southern Canada during the growing season (greater than 50 ppb) are probably sufficient to reduce photosynthesis or to perturb carbon dynamics, resulting in growth reductions of some vegetation.

Classic studies conducted in the San Bernardino National Forest in southern California provide evidence for both tree mortality and growth reduction caused by ozone. The position and elevation of the San Bernardino Mountains east of the Los Angeles Basin allows them to function as a barrier to the movement of marine air and facilitates the development of inversion layers in the Los Angeles Basin. Air pollutants trapped beneath the inversion layer are drawn into the forest at higher elevations by a "chimney effect," resulting from radiant heating on the south-facing slopes. As a result, the San Bernardino and Angeles national forests have the highest forest exposures to oxidants in North America (extreme episodic peaks of 300 to 400 ppb). Exposure to ozone gradually makes some of the needles on the trees in these forests yellow or pale (chlorotic), and eventually these needles fall off the trees. Finally, the trees may be killed by bark beetles or microbial root infection.

Among air contaminants, oxidants may have strongest impact on forests

Ecosystem component or process	Relative strength of evidence[a]		
	Oxidants	Trace metals	Acid deposition
EFFECTS ON NUTRIENT CYCLING			
Increase nutrient availability			
Increase nutrient input	0	1	2
Increase soil weathering	0	0	1
Decrease nutrient availability			
Reduce litter decomposition	0	4	1
Increase soil acidification	0	0	2
Increased cation leaching from soil	0	0	3
Decrease microbial symbioses	1	3	0
Increase aluminum availability	0	0	3
EFFECTS ON PRIMARY PRODUCERS (TREES)			
Reproductive physiology			
Reduce flowering	1	1	0
Reduce pollen	1	0	0
Alter seed production and germination	1	1	1
Foliar physiology			
Reduce photosynthesis	4	1	0
Alter carbon allocation	3	0	0
Increase cation leaching	0	0	3
Increase necrosis	4	1	0
Root physiology			
Decrease water and nutrient uptake	0	1	2
Increase necrosis	1	1	2
Reduce tree growth	4	1	1
EFFECTS ON CONSUMERS OF TREES			
Insect pest activity			
Increase	4	0	0
Decrease	2	0	0
Microbial pathogen activity			
Increase	4	1	1
Decrease	2	2	0
Bird and mammal activity			
Reduce food	2	0	0
Reduce habitats	2	0	0
Increase morbidity and mortality	0	2	0
ALTER ECOSYSTEM SUCCESSION, SPECIES COMPOSITION, AND BIODIVERSITY	4	1	0
INCREASE OR DECREASE BIOMASS ACCUMULATION	4	0	0
TOTAL	44	21	22

[a] Evidence is scored on a scale of 0 to 4 according to its quantity and quality. A score of 0 means that evidence is very limited or that there is only a hypothesis. A score of 4 indicates that evidence is extensive and includes field data. Scores of 1,2, and 3 lie on a continuum between these two extremes.

Which air pollutant is most significant?

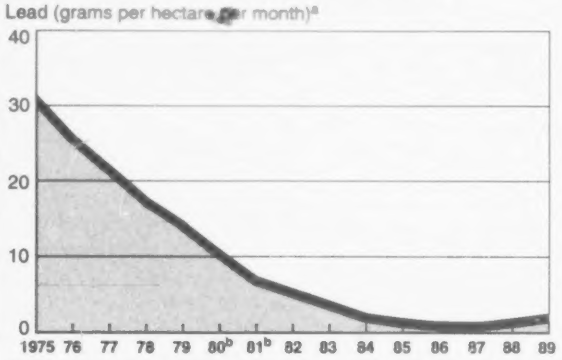
To decide which regional air pollutant is most important for forest health, three issues need to be considered: the strength of evidence linking adverse effects with typical pollutant exposures in large regions; the area of forest that is subject to significant deposition of each pollutant; and the probability of effective pollution management with regulatory strategies.

Many recent large research efforts, such as NAPAP; EPRI's Response of Plants to Interacting Stresses, Integrated Lake & Watershed Assessment Study, and Aluminum in the Biosphere programs; and the Air Quality/Forest Health Program of the National Council of the Paper Industry for Air & Stream Improvement have expanded understanding of the interaction between forest systems and air pollution. From the data generated by these efforts, a case can be made that ozone is the most significant regional contaminant. Moreover, a recent survey mailed to 41 North American forestry and air pollution specialists, chosen to represent a balance of expertise in this area, also found ozone to be the greatest threat to forest health.

In terms of the extent of U.S. rural landscape subject to deposition of regional pollutants, there is substantial evidence to rank them in the following order: ozone, heavy metals, and acid deposition. Rural monitoring shows elevated levels of ozone over wide areas of agricultural and forest regions. Because most heavy metals are associated with extremely fine particles in the troposphere and have very diverse and diffuse sources, they are also widely deposited over rural landscapes. NAPAP has clearly demonstrated that acid deposition is more region-specific because of the more concentrated distribution of primary emission sources, especially for sulfur dioxide in the Ohio River Valley, and the relative efficiency of certain deposition mechanisms, such as cloud-water deposition. As a result, even though the precipitation that falls over most of the U.S. east of the Mississippi has lower than natural pH (about 5.6), the greatest acid deposition occurs at high-elevation sites.

Reductions achieved thus far in regional air pollutants vary greatly according to source strengths, source distributions, available technologies, mitigation costs, and regulatory effectiveness. The requirement for electrostatic precipitators or baghouses on new industrial, utility, and incineration sources has greatly reduced heavy-metal emissions to the atmosphere. In addition, efforts to meet the ambient air quality standard for lead adopted in 1977, including the phase-down in the use

Lead deposition at Hubbard Brook forest has fallen dramatically since 1975



Note: Hubbard Brook Experimental Forest is located in White Mountain National Forest in central New Hampshire, relatively distant from any major local sources of lead. a Includes lead deposited in both wet and dry deposition. b Estimates.

of lead as a gasoline additive, has dramatically reduced the deposition of this toxin in rural landscapes.

In 1973, Yale University's Siccama and I initiated a detailed study of the biogeochemistry of selected heavy metals at the Hubbard Brook Experimental Forest in the White Mountain National Forest in central New Hampshire. This forest is about 70 miles northwest of Boston and relatively distant from any major local sources of heavy-metal emissions. We currently have 15 years of data on the inputs of pollutants from precipitation and dry fallout and the amounts of cadmium, copper, iron, lead, manganese, nickel, and zinc carried away by streams. Over the first 10 years of our study, the amount of lead deposited in our northern hardwood forest was greater than for any other metal pollutant. Lead inputs, however, have declined dramatically since the project began. This decrease correlates extremely well with the decrease in lead concentrations measured in ambient air in urban locations and with the decrease in lead consumed in gasoline over the same period.

The 1990 revisions to the Clean Air Act hold great promise to reduce the precursors of acid deposition over the next decade. The revisions call for a 10 million ton reduction in sulfur dioxide emissions and more than a 2 million ton reduction in nitrogen oxide emissions by 2000. After 2000, sulfur dioxide emissions will be capped, and no increase in total emissions will be allowed.

The ability of the revised Clean Air Act to achieve these high expectations regarding sulfur and nitrogen oxide emissions, however, will be realized only if the rules adopted are fully consistent with the original goals of the act. Some observers believe the regulations now being written by EPA and revised by the White House Council on Competitiveness will, in some cases, allow industrial facilities to increase their emissions of nitrogen oxides when they install scrubbers to remove sulfur dioxide. If so, the overall decrease in the emissions that cause acid deposition will not be so great as those achieved by the scrubbers alone.

The principal precursors for ozone synthesis—nitrogen oxides and hydrocarbons—are also specifically addressed in the revisions to the Clean Air Act. The 1990 act tightens emission standards for cars and trucks, requires reformulated gasoline in certain high-impact areas, and requires fleet operations in designated areas to use unconventional fuels, such as methanol, that are cleaner burning and give off smaller quantities of hydrocarbons.

Alvin L. Alm of Science Applications International in Bedford, Mass., expresses caution, however, regarding the ability of the revised act to bring about compliance with the ambient standards for ozone in the near term. He emphasizes that the stricter emission limits and use of unconventional fuels will help, but uncertainties about specific emission reductions and timetables and the shift of primary responsibility for compliance to the states may make compliance problematic. Thus, I predict ozone is the most significant regional air pollutant that poses risks to the future health of U.S. and Canadian forests.

The future

Intense research efforts of the past 15 years concerning the interaction of air contaminants with forests has taught us a great deal. However, definitive research on forests in the future will continue to be plagued by the following difficulties and limitations:

- Our forests are vast in size, highly variable, and valued for very different reasons by different people; therefore, it is difficult to quantify the extent or the economic losses caused by air pollution damage to forests.
- The subtle perturbations of 10 to 15% in ecosystem-scale processes caused by air pollution in North America are extremely difficult to measure or to separate from perturbations caused by other natural or unnatural stresses.
- Three- to five-year research programs, often funded by the federal government, cannot adequately document forest changes occurring over many decades.
- The subtle stresses regional air pollutants impose on forest ecosystems are not independent of one another or of other stresses and, in fact, are highly interactive.

To effectively address these problems and limitations, efforts must be expanded in two critically important areas—research and monitoring. It must be fully recognized that the applied science of forest health management depends directly on a basic understanding of tree and forest form and function. Greater fundamental understanding of tree biochemistry and physiology is desperately needed.

Further, we, as a society, need more appreciation of basic forest ecology and ecosystem dynamics. Research programs dedicated to specific stress factors must have both field and laboratory components. Studies of mechanisms of disease obtained in laboratories, growth chambers, and greenhouses must be combined with studies conducted in the field to obtain a comprehensive perspective. Efforts in controlled and natural environments must receive equivalent support and encouragement.

In addition, long-term, ecosystem-scale research must be encouraged and supported. Research information must be synthesized and integrated in order to develop models of risk processes and to formulate management options. Predictions of ecosystem toxicology and stress processes must be provided to resource managers, regulators, and decisionmakers.

At the same time, governments must implement a comprehensive environmental monitoring program that will generate accurate information on the deposition of air pollutants in rural areas and that will allow changes in natural ecosystems to be assessed. Air quality monitoring is critical for accurately determining ecosystem exposure and for assessing the efficacy of pollution reduction strategies.

In addition, monitoring ecosystem change is essential to improve understanding of the dynamic nature of complex systems and to correlate change with environmental stress. Separating the effects of chemical pollutants from the effects of changing climate on trees needs to be addressed in monitoring programs. And documenting changes in the pattern of natural landscapes is critically important in order to differentiate natural stresses from man-made ones.

The objectives of the Environmental Monitoring & Assessment Program, a new initiative of EPA, are fully consistent with this need. They include estimating the current status, extent, changes, and trends in indicators of the condition of U.S. ecological resources; tracking indicators of pollutant exposure and habitat condition so as to reveal associations between human-induced stresses and ecological condition; and compiling periodic reports on ecological status and trends.

Regional air pollution is one of the significant contemporary anthropogenic stresses imposed on some temperate forest ecosystems. Gradual and subtle changes in forest metabolism and composition over wide areas, rather than dramatic destruction in the immediate vicinity of point sources over short periods, must be recognized as the primary consequence of regional air pollution in the U.S. and Canada. Global air pollution, including pollution from "greenhouse" trace gases, with its capability to alter fundamental radiation balances of Earth and potential to cause rapid climate change, could also dramatically alter forest ecosystems in the next century (C&EN, March 13, 1989, page 25).

The integrity, productivity, and value of forest and other wild systems are intimately linked to air quality. We must elevate considerations of environmental health to the same level as concerns for human health. Failure to take forest resources into account in considering energy technologies or in the management and regulation of air resources is shortsighted, for it fails to recognize the critical link between the quality of human experience and the quality of our environment. □

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Information Technology

Computers help chemical producers fortify customer operations
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Volume 69, Number 46
CENEAR 69 (46) 1–68
ISSN 0009-2347

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Cover: Sales representative accesses sales data on portable computer during warehouse walk-through. Photo courtesy of FMC

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
(For list of offices see page 67)
Office of Ombudsman: (800) ACS-5558, No. 8–5

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LETTERS

Reanalyzing old extracts

The letter to the editor, "Error in dioxin data" (C&EN, Oct. 7, page 3) suggests that reanalyzing old extracts from water, soil, biota, or human tissue might provide definitive analytical data. However, the letter is silent on the issue of storage stability of the chemicals. Without proper assessment of this issue, one has to wonder about the use of concentration data of chemicals in extracts from the 1970s and 1980s.

The letter further asserts that in the late 1970s and 1980s, the Environmental Protection Agency had a program to save sample extracts for future analysis using "new emerging analytical chemistry methodologies." But who decides if the new methodologies have matured enough to analyze the old extracts? Keeping the extracts as a requirement for Superfund or effluent guideline related work has more to do with legal evidence for a potential litigation than with analyzing the extracts after 20 years to verify or disprove initial concentration results.

Without experimental data about the storage stability of chemicals in extracts, the reanalysis of extracts of water, soil, and so on would, in my mind, be an exercise in futility. The storage stability of chemicals, if not known or determined, raises serious questions about the accuracy and validity of results obtained from old extracts. This will be in the limelight when, as the letter states, "the use of the data is for legal purposes and is of high public interest, such as the dioxin case."

John Mathew
Hazleton Wisconsin Inc.
Madison, Wis.

Research on asphalt

In Robert Dunning's letter (C&EN, Sept. 30, page 5) he questions whether chemists have had sufficient influence on the work that the Strategic Highway Research Program (SHRP) is doing to improve asphalt performance. He also implies that valuable previous work has been ignored. Both impressions are incorrect. The facts are as follows.

The U.S. spends more than $10 billion a year on asphalt pavements. The specifications that are now used to control this massive investment do not ensure good performance—whether the asphalt cracks in cold temperatures, forms ruts in the wheel paths under heavy loads at high temperatures, or forms fatigue cracks under repeated loading cycles. As a result, premature distress is a common sight on U.S. asphalt pavements.

Taxpayers would be well served if the public agencies that build asphalt pavements were able to select materials and designs with more direct control over how these materials will actually perform. Highway agencies recognized this, and in 1987 established SHRP's $50 million program of research on asphalt to find better ways to manage this. SHRP is a thorough, scientific exploration by chemists, chemical engineers, civil engineers, materials scientists, geologists, and others who have expertise on this important subject. Of the approximately 150 scientists and engineers involved in SHRP's asphalt research, about 60 are chemists and chemical engineers. Chemical expertise certainly has not been overlooked, as Dunning argues.

Dunning believes that some specialists—apparently himself included—have known all along how asphalt chemistry affects performance, and how to exploit that knowledge in the selection of materials that will perform well. Some may have speculated about the causes of performance, but proof was certainly lacking. In hundreds of scientific papers reviewed by our research team in the course of its work, and in consultation with the world's experts on this subject, we have found many competing and conflicting explanations in past chemical research literature, none of which adequately explained asphalt's viscoelastic properties. Many believed that micellar structures were key. A few may even have speculated upon the possibility that bifunctional or polyfunctional polar groups were important constituents. However, this last hypothesis was never fully tested nor proven out until SHRP's research team did so, and showed that amphoterics are critical in explaining the viscoelastic properties of asphalts.

Dunning also challenges whether or not the same specifications can cover both neat asphalt and polymer-modified asphalts. While he is correct in pointing

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PRODUCT REPORT

IBM photo

Chemical Industry Counts on Information Technology To Enhance Customer Service

Susan J. Ainsworth, C&EN Houston

It's no secret that the chemical industry has been slower than most to embrace the full potential of information technology. But chemical companies are becoming increasingly aware of how to use these systems to their competitive advantage.

The chemical industry spends an average 1.8% of its revenues on information systems, compared with 2.2% for all industries, according to an early 1991 survey of 35 North American chemical companies conducted by the management consulting firm Index Group Inc., of Cambridge, Mass. That same survey found that major North American chemical companies planned to increase their computer and communications technology budgets an average of only 3.2% in 1991, concentrating their efforts in the customer-focused areas of order processing, inventory, and manufacturing operations. In contrast, other industries planned to boost their information technology budgets about 5.3%, says Index.

To be sure, the current recession, the downward turn in the chemical business cycle, and the Persian Gulf crisis are having a crippling effect on many chemical companies as evidenced by the recent rash of asset cuts, employee layoffs, and cost-reducing measures. Consequently, these factors are having a negative impact on spending on information systems within chemical companies as well.

"After years of industry expansion, many chemical companies are concerned about the economic conditions and the effect [they will have] on both commodity and specialty chemicals profitability," says Thomas A. Nickles, an Index vice president. That means prudent use of information technology is becoming critical, say industry sources. Adds Nickles: "Information systems departments in these companies find that being responsive and cost-effective in the introduction and delivery of new technologies are paramount."

Although chemical companies are cutting assets, employees, and costs, "we've not heard anyone say they want to sell less, deliver less, or be less visible in the marketplace. A lot of that edge will need to come from technology, and information systems will be one of those technologies. Automation will continue to drive down some costs," says Aldona Valicenti, manager of systems development support for the Amoco Chemical arm of Amoco Corp., which was recently named as this year's most effective user of information systems among petroleum and chemical companies by *Computerworld* magazine.

Indeed, information technology is "even more critical" in economic hard times, says James P. Alampi, senior vice president of administration for Univar Corp., of Seattle, the largest chemical distributor in the U.S. In the past if there had been a problem "or we needed to get something done efficiently, we could always hire more people," notes Alampi. But given today's legal and regulatory climate, it takes longer to train people and "it is getting harder to find good people that don't cause you exposure" to regulations. A way to minimize risk, he says, is by investing in systems that provide the information each employee needs so that very few employees have to be experts in many areas. Systems that provide that type of information make it "easier to live through good times and bad times."

Kenneth M. Arnold, chairman of Datalogix International, the Valhalla, N.Y.-based developer of integrated business software for process manufacturers, says, "The most advanced and forward-thinking companies will take advantage of the fact that business is slow now so companies have the time, attention, and people to [implement information systems] right." Information technology "can streamline operations, but it also costs money and takes time to get going before users start to see benefits." At least some chemical companies must be getting the message. Despite the economic downturn, "business at Datalogix has been really good since May," says Arnold.

Valicenti: a cost-cutting technology

Still, companies that recognize the benefits of information systems are not spending freely on them. "Projects are receiving more scrutiny today," says Robert Kramer, information resources manager for FMC's Chemical Products Group. "We tell our users to focus on the applications that are most important to keep operations running. We are spending money where it makes the most sense, trying to hold costs down."

Expenditures that "are not viewed as being directly in support of our customer operation will [probably] fall off priority lists," says Amoco's Valicenti. "Because the chemical industry is operating in an extremely expense-constrained environment, it has to look for those things that will increase efficiency, improve a process, or help it deliver products at a lower cost. I think it's clear that there's just not that much money to spend, so the money you're going to spend will have to provide a bigger bang for the corporation."

Alampi: more critical in hard times

Given that, "one of the things you want to be sure you are able to do is relate what you are doing from an information systems support perspective with the business strategy," adds Valicenti. Many companies seem to be moving in that direction. It's true that many chemical companies are centralizing their staff/support information systems, such as those that handle financial information reporting. But at the same time, they are decentralizing their line operations systems—those relating to their specific business operations.

At Hoechst Celanese, for example, the idea is to make backbone systems, support, or administrative-type systems "as generic as possible across the company so as to run as inexpensively as possible. And [systems used] to order, make, grade, ship, or inventory your product should be driven as close as possible to the manufacturing facility that is producing it," says Edward Phares, vice president of Corporate Information Systems for Hoechst Celanese.

For its part, Amoco Chemical has long set its information technology budget with an eye to business strategy, but now it is taking that a step further. "We continue to negotiate for budget money every year with our chemical company client," says Valicenti, and in order to do that her department must understand Amoco Chemical's business plan. But because "we report directly to the chemical company and are more closely allied with it, we are going to have to take an even closer look at the business strategy. What I hope will happen now is that we will get a link to that strategy even earlier in the cycle," maybe as that strategy is being set.

This kind of early information can sometimes help information systems departments be more effective. For example, if business plans call for the sale or the acquisition of a business, Valicenti says her department can plan ahead to disengage a departing system or integrate new systems. Or if the chemical company is introduc-

Arnold: good time to implement

ing a new product line, she adds, "information technology [managers] ask how we can support the plant [that makes that new product] or the service [component of that new line]. Information technology becomes directly tied to the business."

Another potential benefit to a decentralized information technology is improved teamwork across departments. "If you align your information technology with various business groups and organizations," the business groups take on a greater feeling of ownership for the information technology projects, explains Kramer. At FMC, the responsibility for justifying the funding for an information technology project falls on the business group's steering committee. Thus, the project is viewed as something that can benefit the business group and it takes the same importance as other capital investments.

Phares: a teamwork environment

It used to be that information systems were viewed as a "drain or a necessary evil," says Hoechst Celanese's Phares. But now, at Hoechst Celanese at least, the information systems staff is treated as "a partner to our business counterparts." Those involved in information systems are treated as "team members" who can help make product more efficiently or improve customer or vendor relations, rather than just being "an overhead or a burden. That's a good position to be in." The heads of product lines, for example, are less often complaining about the expense of information technology than they are talking about how these systems are bringing them benefits, he adds. "They want information systems on their team."

This attitude is evident in the "significant investment going on" in information technology at Hoechst Celanese, even while information technology budgets at many chemical companies are being trimmed. The business group leaders have enough "faith and commitment in the information systems staff to believe that it will work with them as a partner to enable them to restructure their business and to be competitive in their marketplace," during economic downtimes, says Phares.

But at the same time, investments in information resources projects should be subjected to the same scrutiny put to other company projects, such as building a new plant, says Kramer. Phares agrees: "You have to run information systems the same way as the guy who is selling fiber or selling commodity chemicals." Information systems heads have to look at how they are staffing their departments, consider where they are putting their investments, and so forth. "Information systems have to be run as a business."

Information technology used to be an overhead type of issue. Managers of these departments "would just keep requesting more money, never looking at the bottom line," Phares says. They would tell senior

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Firms are decentralizing their information technology efforts to streamline operations

As part of their push to operate efficiently during this cost-conscious, recession-weary time, many chemical companies are decentralizing their information technology efforts to bolster their business strategies. At the same time, these companies are also distributing their systems to bring computing power to the desk top, where it can be manipulated and utilized in additional ways.

In the 1980s, "we started seeing [companies] move from central computing platforms, where historically everybody was running off of mainframes, to more distributed processing systems, where you might have minicomputers set up in various divisions within a company," observes Thomas A. Nickles, a vice president of the management consulting firm Index Group, Cambridge, Mass.

"The trend in the 1990s," says Nickles, "is that computerization is really now down to the desk top." More and more of the data, applications, and processing are now getting distributed from what used to be mainframes or distributed minicomputer processors down to personal computers (PCs) and workstations and then onto local area networks (LANS).

Amoco Chemical is a case in point. A few years ago, when PCs started to appear on many desks, they made employees more productive, notes Aldona Valicenti, manager of the company's systems development support. At first, PCs basically gave employees the power to do spread sheets and their own word processing, for example. As the equipment became more sophisticated and easier to use, the employees began to look at how they could make better use of the new level of power on their desks. "So, our migration to LANS was made primarily to share expensive peripherals and files," says Valicenti, "so that more employees could make use of them."

Thanks to this newfound desktop power, applications development and implementation are no longer controlled by and confined to some central group, observes Nickles. Now those tasks are being done on desktop computers, which are still connected to mainframe level computers, he adds.

Although setting up these distributed systems is a challenge, "I think the main issue here is not technological, it's organizational," says Nickles. Rather than just automate the tasks that employees have been doing, this trend is actually "creating job-enriching opportunities for people." For example, with this technology, a clerk can become an analyst, adds Nickles. "There's a lot being written about how the [increased accessibility of data] reduces the need for middle level managers." With this technology change, lower level employees using computers can access the knowledge and information necessary to make the decisions usually reserved for middle management.

"Employees are now comfortable with PCs on their desks. They've developed some applications themselves, and now they are looking at PCs as an intelligent device that allows us to look at data differently than we looked at them before," says Valicenti. PCs, she points out, make it possible to display data more graphically than mainframe systems could by adding color, integrating photos, and other things. Manipulating data in a PC environment can be done "faster, better, and easier," she adds.

Employees becoming comfortable with PCs on their desks

management that they had to buy a certain computer, for example, or they wouldn't be able to compete and "the world would come to an end. But those days are over." Now management is holding information technology departments accountable, he says. "Capital is scarce and that means that information technology departments have to compete against those pushing for other projects that support the operation. And I think that's where we should be. I really do," says Phares.

Knowing what information technologies to campaign for is not easy, say information resources managers. It's a tough job to decide how to apply many of the new, interesting computer technologies that keep evolving. "Doing the right things with a limited budget" is a major challenge, says Valicenti.

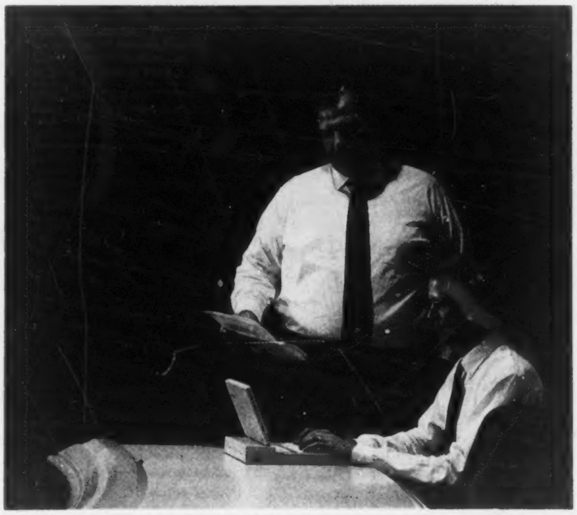
The choices and options are seemingly endless. "We now have personal computers (PCs) and workstations, which are basically more powerful individual computers, and minicomputers and mainframes and control systems with computers under their covers. Each one of these may be doing a part of an [information technology] solution," says Jon Rietzke, manufacturing industry specialist at IBM's Chemical Industry Center in Philadelphia. "In addition, there are networking facilities that are evolving to allow us to interconnect all kinds of equipment and computers, as well as new ideas such as image management, video, and voice technology, for example." The question for chemical company information systems managers becomes: "How fast can I make use of this technology so that my company can reap the benefits and not be overwhelmed?" says Rietzke.

Indeed, information technology managers must be sensitive to the concept that their companies can't handle too much change too fast, says Valicenti. These managers are no longer outside that realm of prioritizing these changes, she says. Quality programs are already at work at many chemical companies, outdating

Aiming to take advantage of employees' comfort levels with PCs and of the PC's increasing processing power, the idea is to "now move processing as close as we can to the person in control of the data," says Valicenti.

Robert Kramer, information resources manager for FMC's chemical products group, agrees. The group's strategy, Kramer says, is to use the PC "as a tool to connect geographically dispersed users and access data regardless of where it resides." The company is in the process of networking all of its PCs with its Digital Equipment Corp. systems. "What we're trying to do is establish an infrastructure such that where the data reside is immaterial to the person who needs it," Kramer adds.

Data used by many people might be stored centrally. Data used by employees at a single location might be put on a local processor. And data handled by only one person might reside on a PC until a project is finished, at which time the data would be disseminated throughout the organization, Kramer explains. Creating such an infrastructure means that access to office systems or to centralized data or any information on any type of hardware is achieved through the same platform or the same workstation. As part of this ambitious undertaking, FMC is "trying to build many of our new systems with the same key strokes as our office systems so that a key stroke represents the same function across all applications."


FMC photo

FMC's Kramer (standing) and Ron Stover use laptop computer to review account reports

With this infrastructure in place, FMC's sales representatives in the field can access the company's mainframe with their PCs and pull up all they need to know about a customer. The shared information system is part of an FMC project that focuses on improving the productivity of the industrial chemical sales force by automating important administration functions as well as by capturing customer-related information. The PC-based data exchange decreases the company's response time in dealing with the changing needs of its customers and increases the amount of time available to sales representatives for direct customer contact. The use of laptop PCs also streamlines the flow of information from the field to the rest of the organization, says Kramer.

Although PCs are handling more applications, there is still a need in some places for mainframe-based systems. "The mainframe is not dead yet," despite what a lot of people keep proclaiming, Valicenti stresses.

She points out that most large organizations have "lots of data in systems that will stay on a mainframe because the investment is too large" to change it. In addition, data that need to be maintained in a central environment because of the security involved or because of confidentiality will likely continue to reside on a mainframe. For example, "I do not think that Amoco Chemical Co. would want to run its financial system on PCs," Valicenti says.

There are a set of applications that from a security, stewardship, and investment-based perspective are going to remain on a mainframe, notes Valicenti. "But I think that the rest [of the applications] are up for grabs or for questioning as to where [they] should run. I really think [it is] this kind of differentiation that's going to continue to go on across the industry."

established business practices and familiar work patterns. Information technology programs can bring on a certain level of culture shock. New systems, she notes, can drastically change how people think and do their work after years of doing things a certain way.

Indeed, in today's highly competitive and cost-conscious business environment, chemical companies can ill afford not to question the way they conduct their business practices and processes. And more and more companies seem to be doing just that. In the 1980s, chemical companies became preoccupied with pulling together the computer-related, automated applications that were developed independently in the 1970s; the key word was "integration," says Index's Nickles. For example, companies found a great deal of value in integrating technology so that an order could be sent through an order entry system and fulfilled through manufacturing. And chemical companies are far from done in exploiting the benefits of integration; in fact, many companies are just now getting integration projects under way. "But, as we enter the 1990s, we are coming to the realization that integration has to be coupled with the redesign of the business processes," a concept that Index terms reengineering, Nickles says.

When the industry began integrating technologies dealing with customer service, logistics, and manufacturing, for example, "we did not change the basic processes—the way people are doing their work," says Nickles. "If you have a mess and you automate that mess, all you are doing is processing that mess faster," explains Valicenti. In the past, "we've automated systems that are already in place or that have been institutionalized without really reexamining if it is still the correct business practice," she adds. A company can install new hardware and new applications and integrate it all, but that company won't see a fundamental change. It won't get the very dramatic improvements in either time, quality, or economics unless it fundamentally changes those business processes, adds Nickles. "But now what we are seeing in the 1990s," he says, "is really an emphasis on changing the business process to reflect a much more integrated set of work."

The concept itself is not necessarily new. What's new is the emphasis. People are talking more than they used to about reengineering. In the past when companies set out to redesign their business process, they did it more "haphazardly," FMC's Kramer says. "Now there are some technologies out there that help you work through this." Companies like Index and Andersen Consulting have put some of these processes in place, he notes.

One tactic Index uses is to work with clients on a cross-functional basis, says Nickles. For example, if it aimed to reevaluate a company's customer service, it would also deal with marketing, sales, logistics, and manufacturing employees "to fundamentally look at how they are doing their work on the business process side."

The trend is taking off because "American companies really have to reposition themselves to compete better in a world market," says Stephen Parkoff, a manager at Coopers & Lybrand, which is also in the business of helping clients redesign their business processes, an undertaking that his firm calls resource productivity analysis.

Many believe in the benefits of the effort. This process helps make a company "leaner and meaner," says Parkoff. "It all boils down to taking a look at business needs and eliminating non-value-added functions." When coming out of a reengineering effort, "I think you end up with a more streamlined business process and organization," says Kramer.

Reengineering can also save companies money on information systems, notes Parkoff. For example, he says, some companies are finding that they are stuck with 20-year-old computer systems that are designed on the basis of the technology and processes in existence two decades ago. Before they lay out $6 million or so to redo their order entry or customer service systems, they may want to first look at the underlying processes. If they can make the processes simpler, eliminate some steps in the way they process an order, or use electronic data interchange to integrate with their customers, for example, it is possible that the new computer systems will be simpler and less costly. "It makes a hell of a lot of sense. That's the kind of dynamics that are going on."

Index's Nickles points up three primary applications of reengineering in the chemical industry. For one, reengineering can be used to look at the way products are developed so as to shorten development cycles. For example, in the pharmaceutical industry, "we can take a process that might take years and try to cut [the development time] in half."

Reengineering is also being used

Computers are used widely in chemical industry . . .

	% of respondees, by job category, using computers^a
Management	99.3%
Production/control	98.1
Process development/design	96.0
Product research/ development	97.0
Purchasing/sales/service	88.9
Other/not specified	89.5
All users	96.7%

. . . with demand for PCs outdistancing other types

	% of respondees using computer type^a
Personal computers	92.3%
Graphics workstations	25.3
Small (mini) computers	31.8
Intermediate computers	26.2
Large computers	34.5
Supercomputers	3.3
One or more of the above	96.7

a Based on 600 responses from a sample of 1500 U.S. C&EN readers, largely ACS members. **Source:** Mar%Stat Market Research & Analysis (Eugene, Ore.) for C&EN/CENTCOM, Ltd.

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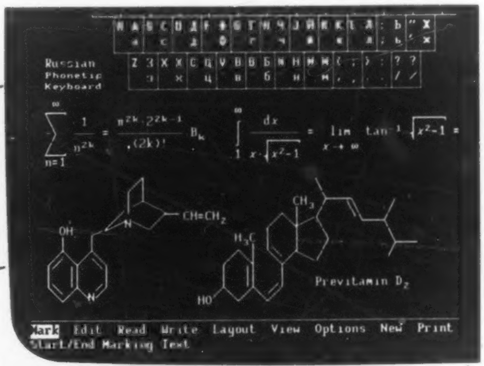
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Chemical industry uses a variety of software

	% of respondees using this software[a]
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Statistical analysis	61.5
Literature searches	48.8
Networking/LIMS	40.3
Electronic data interchange	38.7
Computer-aided instrumentation	38.0
Process control	27.8
Structural databases	25.5
Molecular modeling	16.3
Process simulation	16.3
Materials resource planning	12.5
Expert systems	12.0
Robotics	11.3
Sales/distribution analysis	10.0
Imaging	7.7
Pattern recognition & clustering	7.7
Chemometrics	6.3
Client-server systems	5.8
Environmental modeling	5.5
Artificial intelligence	4.3
Chaos computations	0.8
Other	8.7

[a] Based on 600 responses from sample of 1500 U.S. C&EN readers, largely ACS members. **Source:** Mar%Stat Market Research & Analysis (Eugene, Ore.) for C&EN/CENTCOM Ltd.

for financial consolidation. In such a project under way now, Hoechst Celanese is looking at "reengineering corporate and other finance and accounting business processes and systems to achieve significantly increased business value," says Phares. "What we are looking to do is eliminate functions whose only purpose is to facilitate and coordinate information; replace specialized assembly-line processes with generalized end-to-end functions; simplify organizational responsibilities around business processes; and enhance data accessibility and ease of use of information for key business processes."

A third chemical industry application is improving customer service. Reengineering can be used to figure out how to extend the boundaries of a supplier's technology and business functions so the customer can access select data at its convenience, rather than waiting for the supplier to meet that need. Providing that data is a way to enhance customer service and add a high margin of value.

FMC is currently piloting the reengineering process in one of its fast-growing businesses—its Marine Colloids Division. The business is one that has "developed in an entrepreneurial mode" and is now the size where "it needs new information technology to support continual growth," says Kramer. "We could implement new technology today, but what we would do is institutionalize what are perhaps invalid or old business practices and processes that first need to be challenged and changed."

The company is attacking that project from two angles: internal and external. On the external side, Kramer notes that FMC is looking at how it can grow to be a large organization and still remain the customers' most valued supplier. It is critically evaluating whether "we are easy to do business with" from the time a customer places an order until it receives the shipment. Internally, Kramer says it "is focusing on the way we do the jobs today and really challenging why certain work is performed."

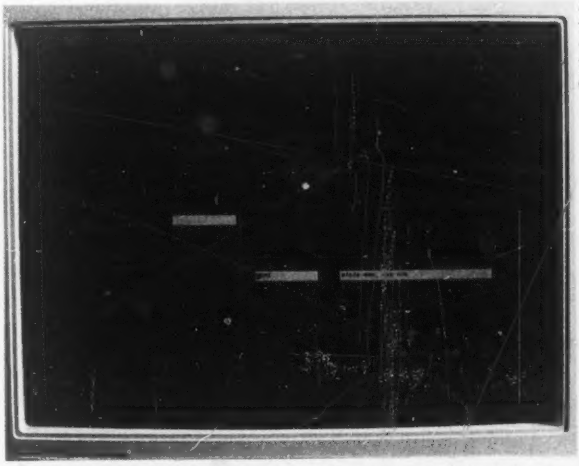
The benefits of reengineering don't come easy. It can take years to begin to understand how the new processes should work. And "people have to be really committed to the process of change and reengineering because you're increasing their work load significantly during that time frame," says Kramer. "Any reengineering effort needs to be driven by the organization who needs the change and not viewed as an information technology project. What we've encountered so far with the Marine Colloids Division is that 80% of what they're coming up with is really process related; only 20% is really information resource related." Besides the commitment of divisional employees, "you have to have commitment at the executive management level," he adds.

When the reengineered process is in place, and "we've challenged the status quo," the company needs to ask "how information technology can be used to institutionalize the better way of doing business," says Kramer. "Information technology becomes a facilitator in the process rather than the driver of the process," he adds.

The computer technology is what "enables us to make these [fundamental business] changes," says Nickles. For example, this technology makes it possible to do business processes in parallel, where they were done sequentially before. Or information technology allows a user to actually eliminate many of the steps in a process through automation.

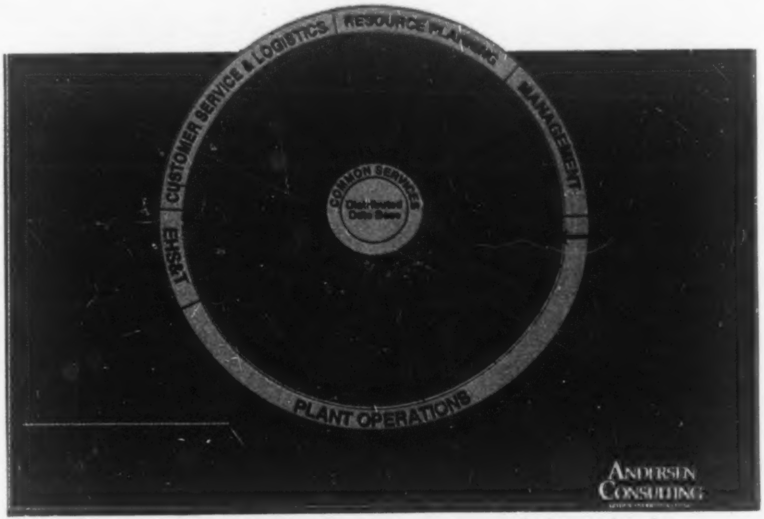
"So we are able to change the business processes in a very fundamental way," says Nickles, "through the use of information technology. The fundamental technology that will support the business process change brought on by reengineering is an integrated set of systems." In other words, when reengineering is completed by an organization, the next hurdle is integrating the systems they've deemed useful to their business.

Indeed, for several years now the chemical industry has been intensely focused on automating and integrating its plant operations, processes, and logistics systems. Many sys-



Datalogix photo

Datalogix's GEMMS Inventory Management Module gives paint inventory via location-lookup window



Andersen Consulting's Process/1 software manages information for applications areas shown in dial

tems have been installed individually. Distributed control systems, for example, tended to grow on their own as an application area; laboratory information management systems were largely built as individual applications, notes Rietzke. "So what you got were a series of applications" that developed independently of one another as "islands of automation." The problem comes when the laboratory wants to be able to access the data coming off of the process control system, for example. "If a company has invested in these individual applications over time and they still do good work, the company can't just throw them away and start over again, because that's just not economical," explains Rietzke.

The alternative is to integrate these islands so they can exchange information. "That's where we feel that a lot of the activity and interest is," says Rietzke. Making information available from one organizational structure to another is the main objective of the growing population of computer-integrated manufacturing (CIM) software programs. Although many of the software applications on the market are labeled as CIM systems, they are not all created equally. Everyone in the industry seems to define CIM differently, seeing systems integration from varying perspectives. Each system takes aim at certain parts of the CIM question, although there is some overlap among product capabilities.

One of those offerings is IBM's 18-month-old Process Operations Management System (POMS), which was developed by a consortium of five process manufacturing companies. The software application facilitates the electronic exchange of information among manufacturing resource planning (MRP), planning, other business systems, process control, and process operations. It accepts a production plan from MRP planning systems; automatically collects sensor, controller, and operator data; automatically reports back to MRP and other business systems; and reports back all production "actuals" to host-based systems, either in real-time or in batches, says IBM. POMS also allows companies to route other transactions or pieces of information on a real-time, dynamic basis around the network, says Rietzke.

Through the POMS Snap-on program, users can enjoy compatibility with an expanding library of software products for such applications as quality assurance lab management, equipment maintenance, statistical process control, and expert system analysis. Participation in the program by a growing list of third-party software vendors is making it easier for users to simply add features to their POMS system rather than add stand-alone systems, according to IBM.

POMS has other objectives, too. "It provides the ability to develop automated procedures on PCs to facilitate the execution of process orders and to collect process data as you get them," Rietzke adds. The product also enables companies to build historical relational databases that can be used in the management of the business. For example, POMS tracks data from process control, operators, quality assurance, and other sources. It also ensures and documents regulatory compliance.

IBM says POMS usage is picking up. During 1990, only a few companies besides the five that helped develop it were involved in pilot projects. In 1991, "there has been a steady stream" of new customers, says Rietzke. "Probably 25-plus customers are now in various stages of POMS implementation programs and roughly 20% of those are in the chemical industry."

Datalogix is another company that has entered the CIM arena. Its CIMPRO software solution, designed specifically for formula-based manufacturers, consists of an integrated set of programs covering a range of functions, including process manufacturing, computer-aided formulation, product costing, inventory, distribution, financial, accounting functions, and regulatory compliance applications. Its open systems environment allows various components to interoperate or exchange information. CIMPRO process software currently runs on Digital Equipment Corp. (DEC), Hewlett-Packard, IBM, Compaq, Bull Information Systems, and Unisys systems. Datalogix has strategic marketing partnership agreements with each hardware manufacturer. CIMPRO, which was introduced in 1981, is in place in more than 370 installations in diverse markets such as bulk and specialty chemicals, pharmaceuticals, printing inks, paints, textiles, specialty coatings, and adhesives.

Just this month, Datalogix has come out with its Global Enterprise Manufacturing Management System (GEMMS) product, which carries CIM one step further. GEMMS was written specifically to take the functionality that Datalogix built into CIMPRO and make it something that can be installed with many different systems at all of a corporation's different plants in their respective divisions so that all of that data can be "rolled up into one integrated whole for the corporation," says Arnold.

While CIMPRO operates at the plant level, the GEMMS CIM system operates on the enterprise level. Besides allowing for integration throughout the entire corporation, GEMMS offers support for multiple platforms, multiple languages, multiple currencies, European tax systems, and multilevel access to organizational information, for example. GEMMS is currently in the second stage of testing in five Fortune 500 companies, including Sun Chemical and Monsanto.

For its part, Andersen Consulting is taking aim at another part of the CIM puzzle. Recognizing that "a major disconnect exists today between the enterprise and process control systems," in late September, Andersen introduced another software product designed for use on an enterprise level called Process/1. According to Karl E. Newkirk, partner and product executive for Process/1 at Andersen, "Process/1 plugs this gap and provides the flexibility needed to help process manufacturers optimize their resources and improve customer response times."

The initial release of Process/1 is available on Digital VAX computers. Process/1's client-server architecture supports multinational operations and provides features such as multicurrency, multilanguage, and unit-of-measure conversion. Andersen says its product comprises five business application areas that are critical to today's process companies: plant operations; customer service/logistics; resource planning; product and financial management; and integration of environmental, health, safety, and training processes.

"As part of our strategic initiative to take advantage of new business opportunities, Process/1 will help us manage information more effectively and will enable us to respond quickly to changes in our market's demand," says Bruce Gordon, director of advanced systems operations at Geon Vinyl Division of B. F. Goodrich in Avon Lake, Ohio, which is currently installing the first release of Process/1.

"This is just the beginning," adds Drew Sellers, associate partner and product manager for Andersen. "Having addressed the critical plant and environmental needs in our initial release, we are hard at work developing enterprise-level applications including customer service/logistics, operations accounting, and resource planning for release in 1992."

There are many instances where big, global process companies can benefit from enterprise software, says Arnold. For example, a company like Datalogix client BASF can use such a system to keep tabs on the thousands of products it makes in hundreds of plants. Without this capability, there's a problem if one of its customers contacts a sales office in one of the divisions wanting to order certain quantities of magnetic tape, carpets, paint, and pharmaceuticals, for example. The customer wants to place the order for all these products, produced by different divisions, but the person taking the order may have no concept of the other groups' schedules. The easy thing for that representative to do is to help the customer with the representative's own product line and refer the customer to other divisions for their information.

But in today's competitive environment that's not good enough. Big multidivisional companies need to give their customers a single point of contact, so they can call a toll-free number, for example, and order any of the many products that the company produces. Enterprise systems, equipped with the power of a relational database, allow a representative to access information for any part of the corporation from a single location.

"We are trying to address what is the very toughest management problem: to centrally manage a huge business like a BASF," says Arnold. It is difficult to transmit corporate demand data down to the plants in a timely manner so that they can execute against it efficiently, and then get the plant's data back to the corporation's business center. "For example, if headquarters gave the plants

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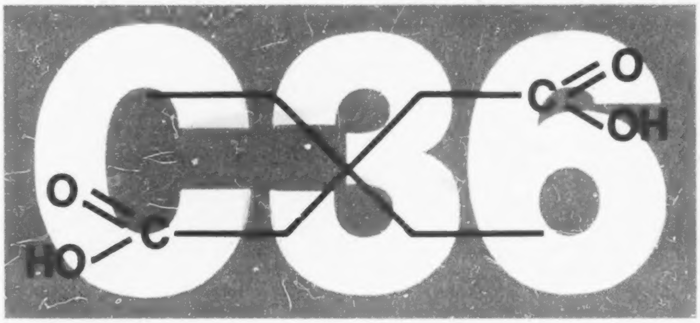

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their marching orders for the quarter and then its biggest customer requested a tremendous quantity of a new product, you really have to look at all the plants that can make that new product and reschedule from scratch to reoptimize." Enterprise systems help a corporation handle these types of situations, says Arnold.

Goodrich faced such a dilemma. What was critically lacking in Geon Vinyl's information management strategy was its ability to capture and integrate plant-level information, including shipping, receiving, production reporting, and most importantly, material control. "We needed a system that would allow us to accurately plan and schedule plant activities—what we'll call campaign management. It had to capture and exchange information with other systems (such as process control and enterprise) during the production process," says Gordon. Andersen's product is now helping it "to integrate information throughout the product development process and help the division better execute the campaign management phase of the production cycle."

Enterprise systems help companies to meet the key business challenges for any manufacturer such as staying close to customers worldwide, operating effectively as a global company, improving quality throughout the company, and getting products to market more quickly, says Arnold. He adds that enterprise software brings "really accurate, timely information where you need it so you don't have to search level after level to find it." And he predicts: "Enterprise software is the generation that is going to move CIM from an intriguing concept to a reality that contributes to bottom-line profits."

Indeed, for many companies, CIM still is nothing more than an intriguing concept. "Everybody is at least [dipping] a toe in the water, and there are some companies that have built advanced CIM plants," says Arnold. It is highly unlikely that any corporation has yet reached the enterprise mode, he adds.

Generally, CIM is still underutilized in the chemical industry, says Tim Challand, product technology manager of process manufacturing for M. W. Kellogg in Houston, which is in the business of developing systems integration solutions for process industry clients. One deterrent may be that implementing CIM at the plant level is a very challenging and time-consuming process.

But "the biggest problem we have in the industry right now is a credibility gap between promises of big savings and upper management's vision of where those big savings are. I don't know that the industry at large has been as good at tracking those benefits and just really showing management that those benefits have been achieved. And if [management] is not convinced of the benefits, then it makes it hard to justify the next expenditure," adds Challand.

Indeed, the benefits of CIM are many. From a product viewpoint, CIM allows companies to more quickly detect "off-spec production" and share that data "so that you can react to it. That's a benefit of CIM that impacts your bottom line because it means you'll be producing less waste," says Phares of Hoechst Celanese, which is implementing CIM at some of its plants.

From a productivity standpoint, CIM enables companies to capture accurate information in a way that allows everybody in that facility to use it at the same time. Without CIM it's conceivable that a single piece of information could be stored in several different places in a facility and vary "depending on whose file it was in," laments Phares.

The sharing of data through CIM also fosters "more of a teamwork environment in a facility." Interdepartmental lines are blurred when data are shared across the organization.

Slowly, chemical industry management is getting the message. Interest and utilization of CIM is picking up. Five years ago, although there were some pioneers in the CIM area, not everybody in the chemical industry felt that CIM was necessary to be competitive, says Challand. "But I don't see that now.

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"I think that most companies have been sold on [CIM] by so many different people that there's almost a mind-set now that if companies don't do this, they're going to be losing out," Challand says. Although management is getting "much more bottom-line oriented" in terms of cost-benefit analysis because of the current recession, "there's just a feeling that they need to go do this," he says.

The benefits of information technology in general are just too great to ignore, say chemical industry information technology managers. A number of factors are forcing the chemical industry to get on the information technology bandwagon and take it as far as it will go.

For one, increased federal, state, and local regulations have resulted in new record-keeping requirements. Because of the volume of detail and the rate at which technical and regulatory information changes, computer technology is the only practical way to maintain data on a current basis and access it efficiently. Collecting information and getting it to a company's own employees, its customers, vendors, transportation companies, and the government is a significant challenge to chemical companies, notes IBM's Rietzke. The Superfund Amendment & Reauthorization Act, for example, requires U.S. chemical manufacturers to report such items as the hazardous materials they use, the quantity used, and the day on which maximum use took place, says Datalogix's Arnold. "That is a hard thing to do without a computer."

Not surprisingly, environmental, safety, and health information systems are drawing "significant management interest in the chemical industry. These requirements are not new, but they are the subject of heavily increased focus," Rietzke says.

Aiming to capitalize on that interest, IBM has developed a new software product to help companies manage information about hazardous substances. Developed in conjunction with Eastman Kodak, IBM's International Chemical Datasheet System (ICDS) is a "comprehensive chemical information management program that allows companies to create, store, and distribute vital safety information wherever and whenever it is needed," says IBM. The product, which runs on a mainframe computer, offers multilanguage support, allowing material safety data sheets (MSDSs) to be created in multiple languages and multiple MSDS formats. When creating MSDS documents, users can rely on a multilanguage library of 1200 commonly used health and safety statements. The ICDS also features "on-demand MSDS queries that allow authorized users to retrieve MSDS forms quickly and easily from system terminals," says IBM.

The inability to collect the right regulatory data in a timely manner can have a big impact on the bottom line. "We had one customer who said it could sometimes develop new adhesives in its lab as fast as in four hours, but it was taking them at least one week to get the regulatory compliance data together. As a result, the company was losing business." Software solutions like CIMPRO can help chemical firms pull together the regulatory compliance data as quickly as they can develop their samples, says Arnold. With that software product, for example, that client "was able to ship the same day."

Andersen Consulting is also ready to exploit the keen interest in these applications. The consulting firm's new Process/1 systems integrates environmental, health, safety, and training processing with manufacturing operations, "providing automatic assists in complying with environmental regulations and promoting the health and safety of employees." Process/1 tracks the quantity and locations of hazardous ingredients in goods and materials and monitors the chemical exposure, medical history, training, and safety records of each employee. "With the onset of more stringent government regulations, the need to secure our employees' safety and to have complete control over any hazardous materials that move through our plants is critical," says Goodrich's Gordon.

The increasing demand of regulation has been one of the main driving forces behind Univar's $50 million investment in an IBM mainframe-based system called UVX 2000, says Alampi. The new system, slated to be completely installed by next April, enables the company to standardize and control information in a central location so that its field staffers do not have to be individually updated on every new reporting requirement. For example, if a person in the field does not do bills of lading for hazardous materials on a regular basis, it would be relatively easy to skip something that is not required for other chemical shipments. "By coding that hazardous material in such as way so that whenever we sell that product, we generate the bill of lading that exactly meets the reporting requirement, or spell out exactly how it has to appear, the field people don't individually have to be brought up to speed on each reporting requirement," says Alampi.

"With larger systems, such as our UVX 2000, the opportunity also exists to introduce software that approaches the application of artificial intelligence in such a way that we can increase safety and regulatory compliance by substituting computer-maintained data on products and the regulations related to them, rather than attempting to rely on human memory," says Univar. "This assures us that it is done right the first time," Alampi explains. "The realm of environmental regulation has become so complex that the more we can standardize, the better off we're going to be. It's a critical point."

Information technology can also provide tools to better link together operations following mergers and acquisitions. After Univar doubled its size in 1986 by its acquisition of McKesson Chemical, the chemical distributor quickly realized that its existing system was inadequate. "We realized that we could not have adequate levels of control of information and understanding at all of our 106 locations unless we had a more centrally directed information system," notes Alampi. The new Univar system is designed to handle such tasks as order entry and warehouse handling and management for the corporation in an efficient manner.

Arnold believes that mergers and acquisitions are fueling the need for enterprisewide systems and open systems. "It's becoming too expensive to retrain people [on new systems] every time they move from department to department." And, for example, if a company sells a division that relies on DEC VAXs to another company that uses Hewlett Packard or IBM hardware, it's not practical to change one of the systems. "There's too much of an investment in hardware, software, and training. Nobody gets a clean sheet of paper. You need software that's going to run on all three vendor's platforms."

Another reason that chemical companies must embrace information technology is because it can help them improve service and thereby better attract and retain customers. An increase in partnering between manufacturer, distributor, and end user has opened up vast quantities of new information to both manufacturers and distributors. Computer-to-computer linkage within the distribution chain allows for dramatically increased levels of electronic data interchange between manufacturers, distributors, and product users, making possible programs such as automatic updating and transmission of MSDS and electronic mail, says Alampi. Electronic data interchange also opens the door for automatic purchasing, and for immediate distribution of information on new product applications to potential commercial users, he adds.

Just around the corner are plenty of new technologies that promise to help make the chemical companies that use them even more competitive. They keep evolving faster than chemical company information technology gurus can implement them. For one, Rietzke expects to see a consolidation of new technologies, such as image management and video, into applications that the customer can use. For that to happen, says Rietzke, "there's a lot of application software yet to be developed. But it will be an interesting future." Amoco's Valicenti agrees: "There are lots of possibilities out there. The future looks bright for implementation of information systems in the chemical industry." ☐

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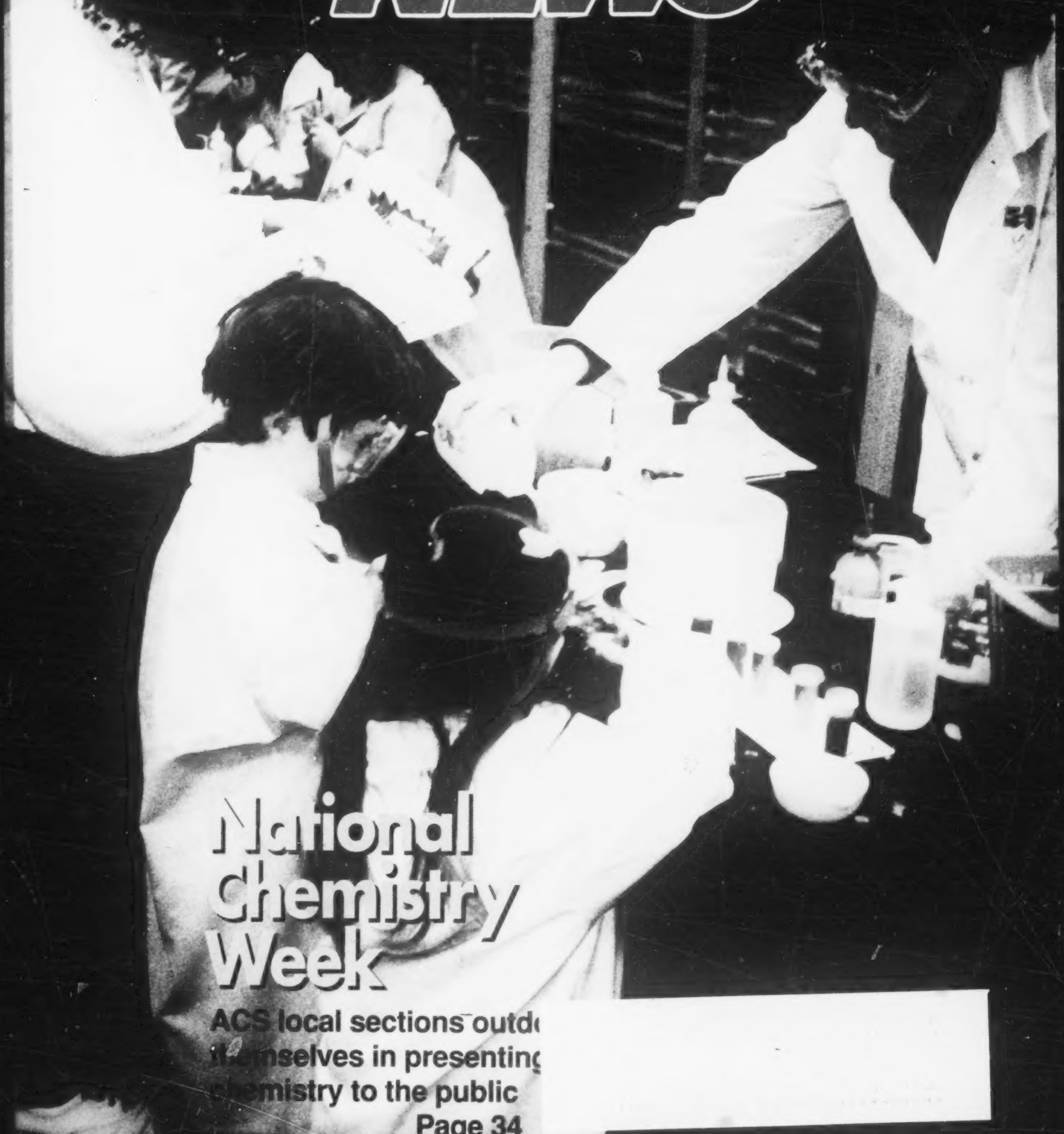
NOVEMBER 25, 1991

CHEMICAL & ENGINEERING NEWS

Carl Djerassi expounds on the often ignored role of mentoring as the foundation of scientific integrity Page 30



National Chemistry Week

ACS local sections outd
themselves in presentin
chemistry to the public
Page 34

CHEMICAL & ENGINEERING NEWS

Volume 69, Number 47
CENEAR 69 (47) 1–56
ISSN 0009-2347

NOVEMBER 25, 1991

News of the Week

- **FDA revamps drug approval program to speed up clearance, but critics fear public protection from unsafe and ineffective drugs may suffer.** Page 4
- **Former ACS Board member Helen M. Free, of Miles Inc.'s Diagnostics Division, wins ACS election for 1992 president-elect.** Page 5
- **Dow Chemical European subsidiary will pay $100 million over three years to purchase 90% of Czech acrylics firm, giving Dow a springboard into Eastern Europe.** Page 6
- **Injecting tons of ethane or propane into stratosphere over Antarctica could stop ozone hole formation by scavenging the chlorine atoms that cause it, suggest three California scientists.** Page 6

Cover: Columbus Section's Family Chemistry Day at Center of Science & Industry. Photo by Robert Schwerzel

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Business

Rohm & Haas' growth plans will continue to include research and development as an essential component. **Page 10**

Government

Legislation to step up research on indoor air pollution is approved by Senate, despite Administration opposition to the bill. **Page 15**

Fiscal 1992 funding for NIH is up 9%, but some spending is deferred until final day of that fiscal year. **Page 16**

Science/Technology

Traditional boundaries of chemistry are broadening in response to changing landscape of science. **Page 18**

First radar images ever made of Mercury indicate possible ice deposits at planet's north pole. **Page 22**

Soil remediation efforts gain momentum with opening of Netherlands plant that washes soil free of contaminents. **Page 24**

Viewpoint

Scientists must give more attention to the mentoring process in effort to prevent science bashing, in the view of Stanford University's Carl Djerassi. **Page 30**

ACS News

This year's National Chemistry Week, the third nationwide public relations extravaganza sponsored by ACS, was a huge success, with an unprecedented variety of activities by the society's local sections. **Page 34**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
(For list of offices see page 55)
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LETTERS

Affectionate respect

Einstein was once overheard to say, I expect inadvertently, "Chemistry is that subject which is too difficult for chemists"—and he didn't even know about low-temperature fusion! What might he have thought about anguish over the popular pronunciation of chemotherapy?

One could, of course, have snapped back at him that theorizing is too difficult for theorists; but let's hear it instead for an affectionate respect of each other in striving for excellence in work and words.

John W. Gibson
Oakland, Calif.

Paint's economic outlook

I have some comments regarding your cover story on the paint and coatings industry (C&EN, Oct. 14, page 29).

Government statistics employ the unit "gallon" to track paint makers' economic performance. In his article, Marc S. Reisch used these statistics to show that although "shipments declined more than 6% for the second year in a row . . . paint makers received a record value for their shipments."

This does not necessarily mean that customers are paying more to paint their wagons. Environmentally responsible paint companies are reducing emissions of volatile organic compounds (VOCs) by manufacturing more concentrated paints. For example, a car that 30 years ago was painted with 1 gal of high-gloss lacquer, today requires only 2 qt of low-VOC polyurethane to cover the same area. Price per gallon, therefore, does not paint an accurate picture.

There is another problem in using gallons to track the paint industry's economic outlook. For most industries, decreased volume sustained over a long period of time signals hard times ahead. This is not necessarily true for the paint industry, which will continue to record declines in total gallons of shipments as paint becomes more concentrated. Similarly, what forecast would be given if there were a sudden surge in gallon caused by (perhaps) introduction to the marketplace of a dilute water-based paint with the durability of an enamel or the weatherability of a urethane?

Not all chemical industries track economic trends through volumes produced. The pharmaceutical industry tracks doses, not grams. The paper industry tracks pages, not weight. Greater insight into the paint industry's economic health could be gained by tracking the amount of solid (or film-forming) material dissolved or suspended in each gallon of paint. These figures are generally available.

Richard S. Valpey III
Low-VOC Project Leader
Sherwin-Williams, Chicago

Chemistry/biology interface

I would like to offer some further insight into the ACS presidential conference on "Expanding the Chemistry/Biology Interface: the Education of Future Scientists," which I organized, as a member of the ACS Committee on Science with other members Harry Gray and Peter Beak, and chaired at Carnegie Institution of Washington on Oct. 16 (C&EN, Oct. 28, page 23). Enthusiastic staff support was provided by Kathi Ream and John Malin. Maxine Singer, president of Carnegie Institution, graciously lent her presence to the conference and gave us the benefit of her experiences, particularly in small colleges, which educate such a disproportionately large number of graduate students in chemistry and biology.

The problem of educating students more effectively at the chemistry/biology interface has effects on the biotechnology industry and our competitive effectiveness worldwide in industries that depend on biotechnology. The discussion at the conference led to the recommendation of a four-point program to provide better opportunities for students to understand both chemistry and biolo-

Notice to members wishing to resign

ACS members who wish to resign their membership at the end of 1991 should do so now by letter to the ACS executive director. Bylaws specify that anyone who fails to resign by Dec. 31 will be carried on the rolls in 1992 as a member and will be responsible for dues. Failure to pay dues does not constitute a resignation.

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DRUG APPROVAL PROCESS: Mixed reviews for FDA reform plans

Reforms would lop 44% off approval time for drugs to treat lethal illnesses

Step	Average review time, months		Time saved, months
	Current	After reform	
Preclinical testing	18	15	3
IND[a] approval	1	1	0
IND phase I (Healthy volunteers)	6	6	0
IND phase II (Hundreds of patient volunteers)	18	34	20
IND phase III (Thousands of patient volunteers)	36		
NDA[b] preparation time	8	4	4
FDA approval Process	30	6	24
TOTAL TIME	117 (9.75 years)	66 (5.5 years)	51 (4.25 years)

a Investigational New Drug. b New Drug Application.

Mixed reviews are greeting a new 11-point program to reform the Food & Drug Administration's drug approval process.

The Pharmaceutical Manufacturers Association paints the program as "one of the most important developments in many years in addressing the inefficiencies of the U.S. drug approval process." But some consumer advocate groups and lawmakers view it as a "thinly veiled" effort to weaken FDA and deter it from its prime purpose: protecting the public from unsafe and ineffective drugs.

FDA has the authority to implement the program immediately, says an agency spokesman. However, several key lawmakers are asking FDA not to carry out the reforms until their committees have an opportunity to thoroughly review and evaluate them.

Developed by the White House Council on Competitiveness, the program is expected to cut up to four years from the nearly 10 years it now takes to bring to market drugs for treating serious or life-threatening illnesses, and maladies for which there are no current treatments. The program will do this by putting these drugs into a fast-track approval process that uses "surrogate endpoints" or other evidence to indicate a drug's effectiveness. For cancer a surrogate endpoint might be tumor shrinkage; for AIDS it might be an increase in a particular white blood cell moiety.

Another means of getting such drugs to market sooner is to standardize FDA's drug approval process with those of other industrialized nations. Such harmonization, the council believes, would move industrialized countries toward common testing procedures that would eliminate duplicative effort.

"Patients with serious and life-threatening diseases will benefit from earlier access to important new drugs, unnecessary regulatory burdens will be eased, and U.S. competitiveness will be strengthened," notes Vice President Dan Quayle. Quayle chairs the council, whose members also include the secretaries of the Commerce and Treasury departments.

The council touts another reform—use of nongovernment scientific experts to perform reviews under contract to FDA—as a way to shrink the backlog of drug applications. This external review process will be used only for those drug applications not likely to offer difficult scientific questions. "We need to supplement our existing talent with some of the strong talent on the outside," says FDA Commissioner David A. Kessler.

Drugs to treat allergies, pain, inflammation, and infections are likely candidates for external review. The council expects such review and other management improvements to cut approval time to seven years from almost 10 now.

However, such external review raises the specter of conflict of interest and delay, charges health affairs activist Sidney M. Wolfe, director of Public Citizen's Health Research Group. "Many [external reviewers] will have financial and other links to the drug industry, which could endanger the objectivity of the review. . . . Reviewers without drug industry connections, who may tend to lack experience in the drug approval process . . . could actually delay approval."

Former FDA chief counsel Peter B. Hutt, who "enthusiastically supports" the reforms, disagrees. "There is a substantial body of members emeritus of FDA advisory committees who have been exposed to the agency and its processes." Many have no links to industry, he notes.

Wolfe also finds the international harmonization reform particularly troublesome, even dangerous. U.S. acceptance of foreign drug testing data "could mean a lowering of our standards," he points out. But Hutt says such standardization "may make our [process] more efficient, not lower it." He doesn't expect harmonization to lead to another thalidomide—a drug approved in Europe but not in the U.S. and which caused severe birth deformities.

Three members of Congress who play a key role in health affairs share Wolfe's discontent. Sen. Edward M.

Kennedy (D.-Mass.), Rep. John D. Dingell (D.-Mich.), and Rep. Henry A. Waxman (D.-Calif.) say, "We are concerned, at a minimum, that the proposals will lead to inconsistent and uncertain standards for review, and could permit commercial interests to override the objectivity that is essential in evaluating drugs."

Moreover, Public Citizen's Congress Watch is concerned about the role and workings of the Council on Competitiveness. "Consumer groups and the public had absolutely no input into these recommendations," says Congress Watch spokesman Nancy Watzman. "But, we suspect, the pharmaceutical industry was intimately involved in their development." The council's activities are closely guarded, with little public accountability, and are not subject to the Freedom of Information Act.

Lois Ember

Helen Free wins ACS presidential election

Helen M. Free has convincingly won the American Chemical Society's election for 1992 president-elect. A professional relations consultant for Miles Inc.'s Diagnostics Division in Elkhart, Ind., and an employee of Miles for the past 47 years, Free also will serve as ACS president in 1993 and as a member of the ACS Board of Directors from 1992 to 1994.

Free has been active in ACS governance for many years, including two recent terms on the ACS Board—as director-at-large in 1988–90 and as Region V director in 1983–85.

According to mail ballots counted last week at ACS headquarters, Free received 18,071 votes, almost 61% of the total. Her opponent, Henry F. Whalen Jr., corporate vice president and director of corporate development at PQ Corp. in Valley Forge, Pa., received 11,723 votes.

Four other directors also were elected to serve three-year terms on the ACS Board—two directors-at-large and two regional directors.

Four candidates vied to become directors-at-large, who are elected by voting members of the ACS Council. The winners were incumbent C. Marvin Lang with 208 votes, and former ACS president Gordon L. Nelson with 189 votes. It will be the second consecutive three-year term on the board for Lang, who is professor of chemistry at the University of Wisconsin, Stevens Point. Nelson returns to the board after a two-year absence, having served a three-year presidential succession in 1987–89 and as Region I director in 1977–85. Nelson is dean of Florida Institute of Technology's College of Science & Liberal Arts, Melbourne, Fla.

The two unsuccessful candidates were Larry F. Thompson and Peter E. Yankwich, with 158 and 144 votes, respectively. Thompson heads the organic materials and chemical engineering departments at AT&T Bell Laboratories in Murray Hill, N.J., and chairs the Society Committee on Chemical Abstracts Service. Incumbent Yankwich, who was running for his third consecutive term, is executive officer of the National Science Foundation's Directorate for Education & Human Resources in Washington, D.C.

In both regional director races, lack of a simple majority among three candidates for each post required adding to the totals of the first- and second-place candidates the second-choice votes on the ballots of the third-place candidates. By this procedure, James G. Bennett Jr. received 1990 votes to win election as director from Region I, consisting of most of New York, New England, Puerto Rico, and eastern Canada. He is principal scientist at General Electric Co. in Selkirk, N.Y. Incumbent Joan E. Shields, professor of chemistry at Long Island University in Brookville, N.Y., received 1884 votes; and William E. McEwen, Commonwealth Professor at the University of Massachusetts, Amherst, got 1014 votes.

ACS voting breakdown

	Votes
PRESIDENT-ELECT	
Helen M. Free	18,071
Henry F. Whalen Jr.	11,723
DIRECTORS-AT-LARGE[a]	
C. Marvin Lang	208
Gordon L. Nelson	189
Larry F. Thompson	158
Peter E. Yankwich	144
REGIONAL DIRECTORS	
Region I	
James G. Bennett Jr.	1990
Joan E. Shields	1884
William E. McEwen	1014
Region V	
John G. Verkade	2262
E. Ann Nalley	1557
Clara D. Craver	1084

Note: In a three-way vote, when no candidate receives a majority, second-choice votes of the candidate receiving the lowest number of first-choice votes are added to the first-choice votes of the other two. Thus, in Region I, Bennett received 1535 first-choice and 455 second-choice votes, and Shields received 1335 first-choice and 549 second-choice votes. In Region V, Verkade received 1873 first-choice and 389 second-choice votes, and Nalley received 1286 first-choice and 271 second-choice votes. a Elected by vote of councilors.

C&EN staff photo

Helen M. Free

John G. Verkade, professor of chemistry at Iowa State University, Ames, received 2262 votes to win reelection as director from Region V, which encompasses much of the Midwest, Texas, and parts of mid-Canada. This will be his second full term (counting a previous partial term, he has served since 1987). E. Ann Nalley received 1557 votes and Clara D. Craver 1084 votes. Nalley, who was nominated by petition, is professor of chemistry at Cameron University, Lawton, Okla. Craver is president of consulting firm Craver & Craver Inc., in Glendale, Mo.

Members also overwhelmingly ratified two amendments to the society's constitution. They remove gender-specific pronouns from the constitution, and create a mechanism to establish ACS international chemical sciences chapters.

Ernest Carpenter

the bill to the floor. Lautenberg is one of the bill's original cosponsors. In terms of public health, Lautenberg expects that "this bill will provide us a much needed ounce of prevention and help us to avoid the costly pound of cure."

The bill calls on EPA to report to Congress on the subject of chemical sensitivity disorders, including multiple chemical sensitivities. The report is to address the underlying causes of these disorders, identify their prevalence, and make recommendations for actions to prevent and respond to such illnesses. EPA is also to analyze the adequacy of existing ventilation standards and guidelines to protect public health, and the National Institute of Occupational Safety & Health is to carry out a program to demonstrate methods of assessing and mitigating indoor air contamination in "sick buildings."

In addition, the bill directs EPA to develop a national response plan identifying actions to be taken to reduce indoor air contamination; establishes an office of indoor air quality within EPA; sets up an interagency council on indoor air quality to oversee the indoor air activities of various federal agencies; and provides incentives, in the form of grants, for states to develop their own air quality management and assessment strategies.

To carry out all these programs the bill authorizes total funding of $48.5 million per year for each fiscal year from 1992 to 1996. That yearly figure breaks down into $20 million for research and health advisories; $12 million for state management and response grants; $10 million for EPA operations; $5 million for the building assessment program; and $1.5 million for the interagency council.

Janice Long

NIH budget up 9% but some spending "on ice"

Fiscal 1992 funding for the National Institutes of Health is up 9% to just over $9 billion in the budget given final approval by Congress earlier this month. On a percentage basis NIH didn't do as well as the National Science Foundation or the Department of Energy in the 1992 budget battle, but it is still the largest supporter, by far, of nondefense R&D. Its nearest competitor, the National Aeronautics & Space Administration, has a fiscal 1992 R&D budget of $6.4 billion (C&EN, Nov. 4, page 26).

However, Congress put a special twist on NIH's budget this year. It told the agency that it cannot spend $563 million, or 6%, of its current budget until the final day of the fiscal year—Sept. 30, 1992. The institutes with the highest percentage increases also have the largest percentage deferrals. For example, the National Cancer Institute, whose funding is up 16% to just under $2 billion, cannot spend 11% of that until Sept. 30. For most of the institutes the deferred spending ranges between 4 and 6% of their total budget.

This sleight of hand, which pushes the actual expenditure of funds into the next fiscal year, was necessary to keep overall expenditures for the departments of Health & Human Services, Education, and Labor within their fiscal 1992 budget allocation. Deferred funding for all of them totals $3.1 billion. "Without these delays," Sen. Tom Harkin (D.-Iowa), chairman of the appropriations subcommittee that deals with the three departments, told his fellow Senators, "The bill would be cut to the bone and held to levels below last year."

However, this sleight of hand wasn't to everyone's liking. Sen. Pete Domenici (R.-N.M.), ranking minority member of the Senate Budget Committee, voted against the conference report on the Labor-HHS appropriations bill because of the budget gimmicks it contained. Domenici had another problem with the bill. "Even for the federal government," he said, "it's difficult to spend that much money in one day."

Janice Long

Congress gives NIH more funds than Administration sought

$ Millions	1992 Congressional appropriation	1992 Administration request	1991	% difference appropriation-request	% change 1991-92
National Institutes	$8177.2	$7982.0	$7439.1	2%	10%
Cancer	1989.3	1810.2	1713.8	10	16
Heart, Lung & Blood	1199.4	1209.9	1126.9	−1	6
Allergy & Infectious Diseases	971.1	976.7	907.3	−1	7
General Medical Sciences	818.9	833.2	760.2	−2	8
Diabetes, Digestive & Kidney Diseases	664.1	658.6	615.3	1	8
Neurological Disorders & Stroke	583.4	583.4	541.7	0	8
Child Health & Human Development	524.4	520.6	479.0	1	9
Aging	387.0	348.6	323.7	11	19
Eye	271.0	272.3	253.2	−1	7
Environmental Health Sciences	253.9	254.5	241.0	0	5
Arthritis & Musculoskeletal & Skin Diseases	204.5	204.8	193.2	0	6
Dental Research	160.4	160.9	148.9	0	8
Deafness & Other Communication Disorders	149.8	148.3	134.9	1	11
National Center for Research Resources	315.2	321.0	335.3	−2	−6
National Center for Human Genome Research	105.3	110.5	87.4	−5	20
Other	412.7	361.4	415.1	14	−1
TOTAL	$9010.4	$8774.9	$8276.9	3%	9%

Note: Fiscal years. **Source:** H. Rept. 102-282

NOTE

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Program for PITTCON '92
in New Orleans
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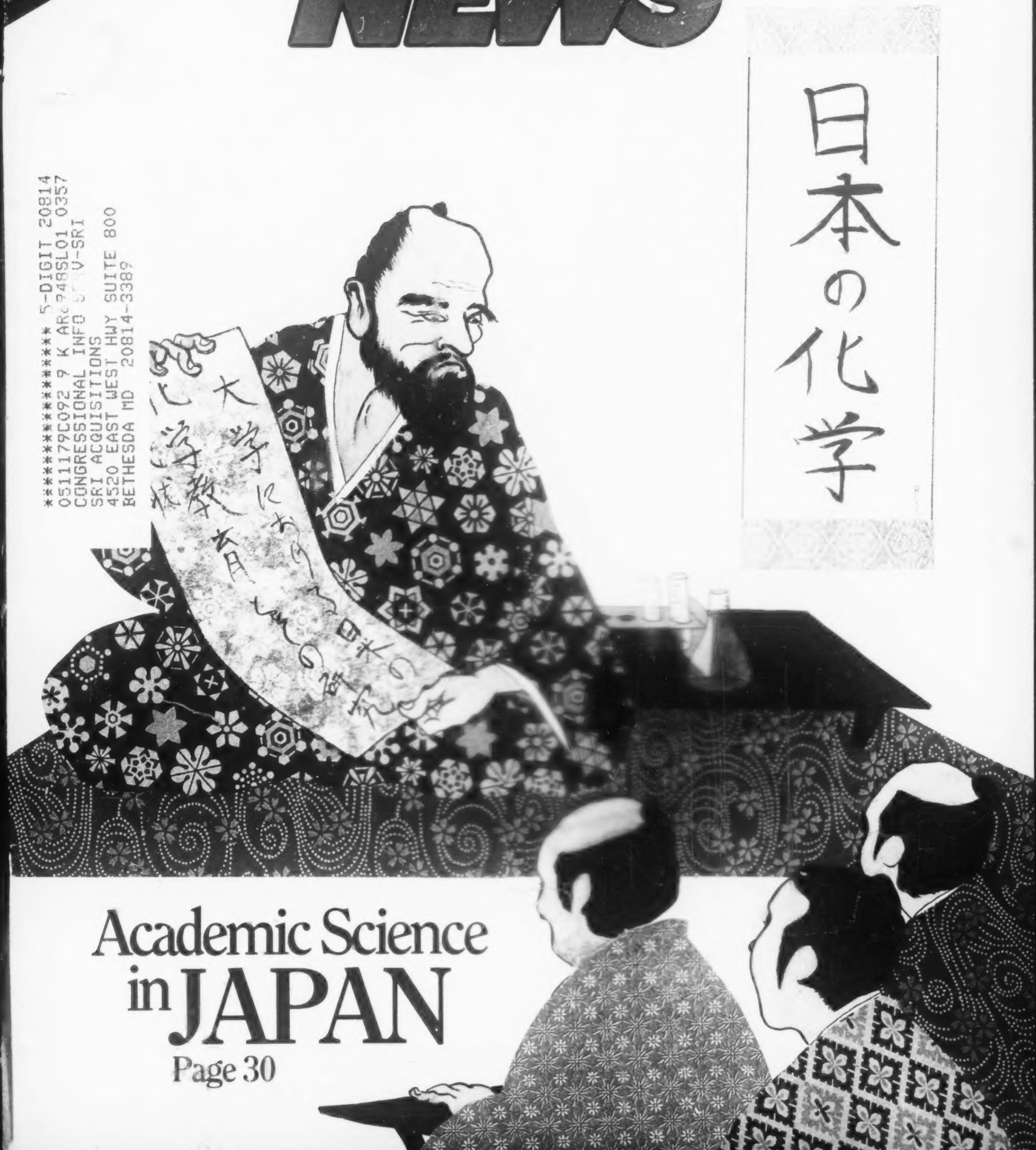
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Academic Science in JAPAN

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Volume 69, Number 48
CENEAR 69 (48) 1-76
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

DECEMBER 2, 1991

News of the Week

- **Stanford University chemists have developed a method to selectively break specific bonds in a triatomic molecule using a tunable infrared laser.** Page 6
- **White House Council on Competitiveness, charged with ensuring federal regulations don't overly burden industry, draws fire from Congressional Democrats for actions they call too secretive and possibly illegal.** Page 7
- **Recent changes in structure and management at NSF have hurt morale, triggered complaints about director Walter Massey.** Page 8
- **U.S. plastics producers have formed an industry group involving top executives in coordinating and improving plastics recycling, conservation, and resource recovery programs, and in dealing with public concern about plastics and the environment.** Page 8

Cover: Illustration by Deborah Bix

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Business

Increasing demand for oxygen and nitrogen bolsters profits for industrial gases, spurs producers to add capacity. **Page 13**

Government

Cryofracture's long development and testing time may rule out its use as an alternative chemical arms disposal method. **Page 19**

Congress increases Department of Defense's 1992 R&D funding 10% to $39.3 billion, 2% less than the Administration requested. **Page 21**

Science/Technology

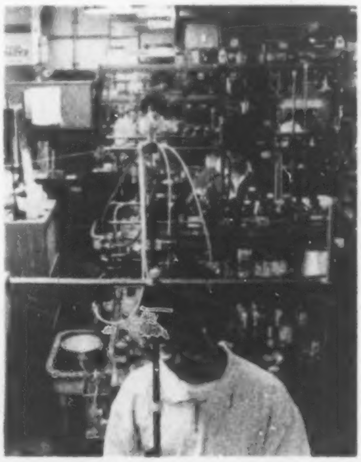
Separations technology field growing, fueled by drive for increased yields, despite long neglect by industry and education groups. **Page 27**

Books

"Science Matters: Achieving Scientific Literacy" by Robert Hazen and James Trefil stresses goal of science education for the nonspecialist as using science, not doing it. **Page 47**

Meetings

1992 Pittsburgh Conference (officially PITTCON '92) miniprogram includes listing of technical program together with registration and other information. **Page 56**



Special Report

Japan is slowly changing its infrastructure for academic science and education as economic success transforms the country, fueling its efforts to catch up scientifically with the U.S. and European countries. **Page 30**

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(202) 872-4600; TDD (202) 872-4432
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Alternatives for diabetes

The article by Stephen Stinson, "New Drugs Under Development for Diabetes" (C&EN, Sept. 30, page 35), did not contain any discussion of the potential role of micronutrients in the prevention or mitigation of diabetic complications. There is ongoing research into the effects of vitamins C and E, chromium, and omega-3 fatty acids in reducing sorbitol levels, stabilizing cell membranes, reducing platelet aggregation, improving blood sugar control, and correcting blood lipid patterns.

Many laboratories are studying these nutrients in relation to diabetes and have published encouraging reports. If the beneficial effects are confirmed, these agents offer safe and relatively inexpensive alternatives or adjuvants to the drugs that are under development.

Burton Kallman
Director, Science and Technology
National Nutritional Foods Association
Costa Mesa, Calif.

Chemistry-biology interface

I was delighted to read about the ACS meeting of educators aimed at improving relations between the chemical and biological sciences (C&EN, Oct. 28, page 23). Lest we be too parochial, the same problems exist with other disciplines. Actually, chemistry can be a unifier because chemistry is what chemists do. We are in space research, biotechnology, biomedicine, electronics, telecommunications, and so forth. We are involved in basic and applied research, engineering, technology, marketing, sales, information services, law—you name it.

How do we get this across to the high school student, the college student, faculty members, and ACS members? Yes, we should have more conferences at the interface disciplines. But at some point, let's put all of this together. I personally have never been more excited by the opportunities afforded to chemists at this time. How do we get this across to others? I think we must lead in an education reform that addresses not only the national education problems and the attractiveness of chemistry as a profession for the young, but also the real problems of many of the chemists who are already practicing.

I don't believe our own membership fully appreciates the opportunities, directions, and options that are available to them at the discipline interfaces and also throughout the work force. ACS must have this as a thrust area in order to continue not only as a science society, but as a professional society concerned with its members and their opportunities, as well as with the relationship of those in the profession to the world around them. The time is also ripe for ACS to lead in developing multisociety alliances as well as in finding more economical routes for multisociety memberships as part of these directions.

Eli M. Pearce
University Professor
Director, Polymer Research Institute
Brooklyn, N.Y.

Rarely have I read more high-minded balderdash than in the article "Chemists, Biologists Seek Better Relations." Indeed, the statement that "the first semester of freshman biochemistry should be a slow introduction to the topic, largely inorganic in subject matter, and designed not to discourage students" borders on the surrealistic. How do you teach molecular biology when they can't tell a mole from a molecule?

There are indeed many problems with undergraduate chemistry education—in particular, the undervaluation of biochemistry—but the cause of change is not advanced by the self-serving and specious comments of the distinguished speakers. Would it not have been possible to invite someone who teaches ordinary undergraduates?

Does Bruce Alberts really believe that "the chemistry taught to such students hasn't changed in decades"? Has he compared Fieser and Fieser with John McMurry, or examined the successive editions of Morrison and Boyd? Is he so young that he does not remember that the sophomore year used to be devoted to qualitative inorganic analysis and quantitative analytical chemistry and that the scourge of a gently mathematical physical chemistry was reserved for seniors?

As a former member of the Committee on Professional Training, Harry Gray should be ashamed to claim that "the four-year undergraduate program has not changed in 50 years with general chemistry in the first year, organic chemistry 'dug in' and dominant in the

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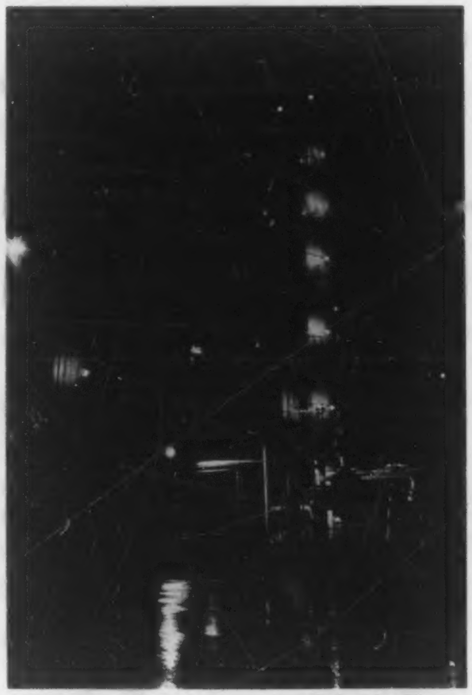
Rising Demand for Industrial Gases Paves Way for Price Increases

Improving prospects for oxygen and nitrogen brighten earnings outlook for producers and spark small round of capacity expansions

Bruce F. Greek, C&EN Houston



Air Products' 400 ton-per-day Orlando, Fla., plant produces nitrogen, oxygen, and argon

Despite the recession, in several parts of the country demand is increasing for the two major industrial gases—oxygen and nitrogen. Thus, producers have been able to push through a recent round of price increases. And with improved prospects for earnings, producers once again have begun increasing capacity, although total additions are small when compared with the large capacity expansions of 10 to 15 years ago.

With the current strengthening of demand for industrial gases (including argon, which is largely coproduced with oxygen), output of oxygen in 1991 is expected to be about 465 billion cu ft, up slightly from 462 billion cu ft last year. Output declined during the first half of the year, but it currently is rising. Nitrogen output this year is forecast to be up more than oxygen, about 2.5%, to 770 billion cu ft. Production of argon this year likely will be up only slightly from last year's output of 12.9 billion cu ft.

The difference between these growth rates is a result of the varying activity in the major markets of each gas. Organic chemical production, which requires the largest amount of nitrogen for blanketing and inerting, has continually operated at record volume levels this year. Steel making, the largest use of oxygen, however, has been weak because of declines in construction and automobile production. In most instances, other markets for these industrial gases are showing small increases.

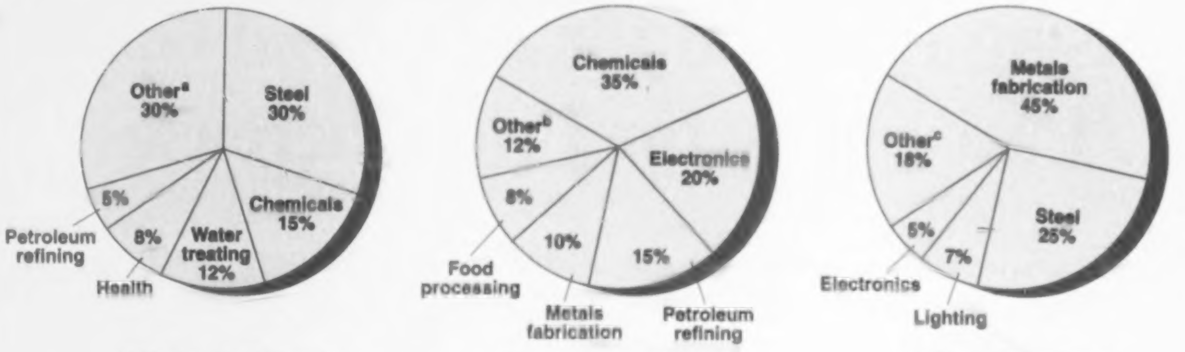
Output of these industrial gases is expected to reach record levels. For example, demand for oxygen is likely to improve because of its increased use in the steel industry as well as in chemicals and other small uses, says William J. Koeppline, vice president for on-site gases at Union Carbide Industrial Gases' Linde Division. Nitrogen demand could grow faster than oxygen, mainly because of higher growth in its traditional uses such as electronics manufacturing; chemicals; food freezing; and fabrication of metals, plastics, and rubber. Argon also is expected to tack on a small increase in demand.

Longer term, growth for oxygen and nitrogen is forecast to average 3 to 5% annually. Both new uses and greater recognition of the value added by increased use of these gases will drive the growth, says Thomas H. Tough, general manager of marketing at Air Products & Chemicals. Better service by suppliers of gases also will spur growth, he adds.

Production of industrial gases by noncryogenic methods likely will grow much faster than production by the conventional method—air separation at cryogenic temperatures. Pressure swing adsorption (using molecular sieves) and membrane permeation (hollow fibers often made of organic polymers) processes to separate oxygen and nitrogen are continually being improved to give higher volumes and purities at lower costs. For example, earlier this fall, Air Products began to offer commercially a system to supply noncryogenic nitrogen in relatively small volumes at low cost to metal heat-treating companies. The system will allow control of the oxygen concentration within the nitrogen of up to 10,000 ppm and to within 5 ppm tolerance.

Some new technologies are on the horizon that would require significant increases in the use of oxygen, says Bryan P. Haley, vice president of marketing and commercial development at Airco Industrial Gases. If direct injection of coal instead of coke in the steel-making process gains wide use, oxygen demand for steel could jump. As it is, oxygen use per ton of steel slowly increases annually on average, he says. Signifi-

Use of oxygen, nitrogen, and argon breaks down this way



1991 oxygen demand = 465 billion cu ft

1991 nitrogen demand = 770 billion cu ft

1991 argon demand = 13 billion cu ft

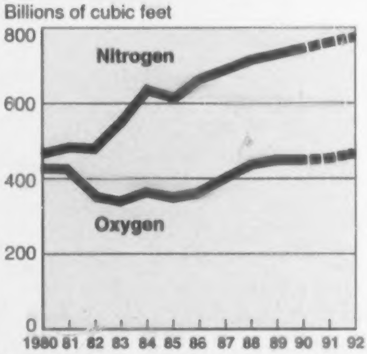
[a] Metals fabrication (cutting and welding), ceramics pulp and paper, electronics, distributors, and National Aeronautics & Space Administration and other agencies. [b] Oil and gas production, rubber and plastics fabrication, float glass, miscellaneous blanketing and inerting uses, distributors, and NASA and other agencies. [c] Primarily distributors to small-volume uses. Source: C&EN estimates

cant increases in oxygen demand are coming in pulp and paper manufacturing as the use of chlorine is replaced, in aluminum smelting as recycling grows, and in wastewater treatment as more oxygen is needed to make ozone.

The growth in these and other technologies using oxygen is beginning to put pressure on the available capacity in certain parts of the U.S. For example, because liquid forms of industrial gases cannot be shipped very far economically, the supply of oxygen has become tight in the Southeast, yet is plentiful in the Midwest.

Across the country, however, capacity use is increasing. The operating rate of air separation plants in 1992 will top 80% of nominal capacity, up from about 72% in 1987, Haley says. He suggests that the practical limit to operating rates on average is about 85% of capacity, to allow for maintenance and other outages.

Oxygen, nitrogen production to reach record highs



Note: Production from all sources except manufacture of ammonia and derivatives. **Sources:** Department of Commerce, C&EN estimates

Capacity expansions under way are either completely new plants or process improvements of varying size at existing plants. New air separation units continue to have economic advantages over older units, largely because of lower energy requirements. The investment cost of adding process improvements may be balanced by energy savings and may affect whether an older plant is kept operating.

Profits from the price increases, ranging from 5 to 10% earlier this year, spurred producers' decisions to expand capacity. But much of the price rise has gone to cover higher energy costs and only partly to offset declines in prices that occurred during the 1980s. Supplies of industrial gases probably will have to grow tighter and prices increase more before other large capacity expansions are announced.

Industrial gases frequently are sold under long-term contracts containing at least three clauses relating to costs of energy, productivity, and labor that can adjust price, points out John F. Walden, vice president of Big Three Industries of Houston, a subsidiary of France's Air Liquide. Big Three Industries sells a very large portion of its industrial gases through a pipeline system along the Gulf Coast, primarily to chemical makers and petroleum refiners. Strength in these markets has led the company to begin a program that will add more than 30% to capacity by 1994.

No fixed list prices exist for the major industrial gases. Volume, equipment, purity, and service enter into pricing formulas. On a unit basis, gases delivered in cylinders cost many times more than those delivered by pipeline, with the cost of gases delivered as liquids and put through a supplier's regasifier falling in between. In volumes of several million cu ft per year, high-purity oxygen and nitrogen cost about 35 cents per 100 cu ft, and argon about $2.00 to $2.50 per 100 cu ft.

Most argon is sold in high purities, with relatively little going into electronics-grade purities. Its major uses—specialty steels (mainly stainless) and other metals, welding, electronics, and light bulbs and tubes—all are growing modestly. Production of this gas likely will top 13 billion cu ft this year.

With prospects for improving demand during this decade, users of the major industrial gases may encounter supply problems. If past performance is an indicator, however, producers will meet the growing demand, assuming that selling prices rise enough to keep capacity expanding. □

Special government funds support basic research in key fields

The Japanese government is making a major effort to encourage basic research in a number of key areas. Several ministries sponsor these targeted programs in basic research. As in the U.S., most government-supported basic research is performed at universities, although company research labs and national laboratories play a key role in some of the targeted research programs.

The major source of special project grants for universities is the Ministry of Education, Science & Culture. Proposals for these grants are not so detailed as those required by the National Science Foundation or National Institutes of Health in the U.S., and the selection process for proposals is also far less rigid than the thorough peer review system followed in the U.S. The Japanese language is a major handicap in writing proposals because of the slow speed of Japanese-language computers.

These grants come in four general types. General-purpose grants cover equipment, reagents, and glassware. These range in scope from grants of $75,000 to $365,000 over four or more years to purchase major pieces of equipment, such as NMR instruments or mass spectrometers to single-year awards in the range of $20,000 for reagents and glassware.

A second category is targeted project grants. These $1 million to $3 million grants over the course of three years are awarded to giant project teams that involve 30 or more research groups, called kozas. In any given year, five or six of these grants will be in chemical fields, for topics such as dynamic natural products, gangliosides, or hypervalency. The kozas that make up the project team hold two open meetings to report their progress each year and usually have an additional meeting to discuss ongoing work. Each member koza receives a grant from the project of about $30,000.

I would prefer to see these grants distributed independently to the same number of research groups following a fair selection process. Under the present arrangement, the head of the research team exerts too much influence on the member kozas. This pyramidal hierarchy mirrors the prevailing pattern throughout Japanese culture and has to be curbed. A smaller team of research groups could more effectively advance a research area.

Another problem with these large project team grants is the amount of time required to attend the group gatherings. Since results coming from the grant-supported work will appear in scientific journals, preparation of progress reports and final reports for these projects is redundant.

The Ministry of Education, Science & Culture also awards special promotion grants to outstanding research groups. These awards of about $1.5 million over a period of three years are particularly attractive because they are the largest grants available to individual kozas. Recipients are active researchers at the forefront of Japanese science and are selected on the basis of their achievements and reputation. Chemistry usually receives three to seven of these grants each year.

The fourth category of grants is seed grants, awarded for one year to researchers who are less than 37 years old. These grants are usually for less than $9000.

In order to encourage more students to enter Ph.D. programs, the government – through the Ministry of Education, Science & Culture – has initiated a Special Graduate Student Program, which provides students with stipends of $880 per month. Ordinarily graduate students receive loans from the government of $580 per month, which they must repay unless they become teachers. Under the Special Graduate Student Program, students can also apply for research grants of $7300 per year. Some

Frontier Research Project, begun in 1986 and funded by the Science & Technology Agency. All of these new ventures stress interdisciplinary collaboration and have an international flavor.

Many government agencies are striving to create projects with novel concepts. But when too much emphasis is placed on grand projects, more subtle basic research that does not appeal to mass media tends to be forgotten. Without quiet, fundamental research, basic findings leading to the more media-appealing technological or medical discoveries will inevitably be weakened.

In view of the importance of basic science to industry, the Ministry of International Trade & Industry, which has for many years actively promoted and subsidized technology development in industry, has started to consider subsidizing university laboratories. Industry also realizes that it has an important role in rapidly transforming the old image of Japanese science. It is increasingly subsidizing academic research, as well as performing first-class interdisciplinary research within its own research laboratories.

Lagging behind these organizational and financial transformations is the human response at universities. Japanese universities have considerable autonomy, and could, at least in theory, develop and implement their own unique programs. The senior professor's rank is comfortable, however, and, in certain cases, this comfort may be dampening the drive to introduce drastic changes.

Probably a more serious problem for universities, however, is that the various parts of national universities are too autonomous. An American university is more autocratic: Presidents, deans, or department chairmen have far more authority than their Japanese counterparts and can make important decisions with much less consultation with other faculty. In Japan, universities have an excessive number of committee or general meetings at practically every level. Japanese professors spend many more hours in committee and faculty meetings, and decisions are overly based on consensus. Monthly faculty meetings are attended by all professors, which, in the case of the faculty of science, includes those in chemistry, biology, physics, mathematics, and several other fields. Professors are entrapped by these meetings, which are a steady drain on their time. The Japanese people are more "polite" and less outspoken than their American counterparts, so their

Fiscal 1989 funding	$ Millions
Ministry of Education, Science & Culture	**$397.9**
Scientific research	384.0
Special graduate and postdoctoral program	13.9
Science & Technology Agency	**75.1**
Basic research	10.2
Basic interdisciplinary research	5.8
Postdoctoral program	2.2
Creative Science & Technology Program	33.6
Frontier Research Program	12.4
Human Frontier Science Program	10.9
Ministry of Health	**40.0**
Ministry of International Trade & Industry	**56.2**
Basic industrial technology for the future	49.6
Human Frontier Science Program	6.6
Ministry of Agriculture & Fishery	**5.8**
Ministry of Postal Services	**0.7**
TOTAL	**$575.7**

Note: Figures are for the year ending March 31, and are converted from yen using the rate $1.00 = 137 yen. **Source:** Science & Technology Agency of Japan

postdoctoral fellowships are also available, with priority for these fellowships given to candidates who transfer to groups other than the one in which they received their graduate training.

Japan has been criticized for the large imbalance between the number of Japanese who study in the U.S. or Europe and the number of scientists from those countries who come to Japan. To address this issue, both the Ministry of Education, Science & Culture and the Science & Technology Agency have initiated postdoctoral and cooperative research programs that support invited foreign scientists in Japanese government and university laboratories.

The Science & Technology Agency also provides grants to support basic research programs in a number of fields. Its grants in creative science and technology are for five years and support teams of government, industry, and university laboratories working in designated areas. Currently the areas being supported are materials science, life science, communication science, and marine science. Although the grants are appreciated, they require far too much paperwork, including frequent progress reports.

Another innovative approach of this agency is the Frontier Research Program begun in 1986 by Ryogo Kubo, an emeritus professor at the University of Tokyo. Its offices and impressively equipped laboratories are in buildings adjoining the huge Institute of Physical & Chemical Research (known as Riken) north of Tokyo. Projects run on five- to seven-year contracts and are headed by top-quality team and group leaders. The program operates by a flexible and cosmopolitan system quite different from traditional research teams. Group leaders and staff are recruited internationally, and the program's scientific advisory group also includes several foreign scientists. The second set of eight-year projects under this program started in the fall of 1991 under the direction of Masao Ito. Their topics are the functioning of mental processes, frontier materials, saccharide information storage, and plant homeostasis.

Binational and multinational cooperative research projects are supported by grants awarded by the Science & Technology Agency and the Ministry of International Trade & Industry. Under these grants, each member research group receives about $25,000.

Koji Nakanishi

faculty meetings go on and on, chewing up precious time.

Despite these drawbacks, the concerted efforts going on in Japan mean that the transition will continue and the conduct of basic research in academe will inevitably change for the better. The overhaul of the research system will probably be quite slow at existing universities, but many new education and research institutes have already started, and here change will be much more rapid.

As mentioned earlier, Japan is in the process of ecdysis to a more modern image and structure. There is no question that the overall level of chemical education and research is presently higher in the U.S. than in Japan. However, in terms of plans for future development, the picture for Japan seems brighter. Numerous ambitious plans are being realized in Japan, thanks to its prospering economy. This contrasts favorably with the present overall atmosphere in many other countries, where the major concern is how to stop erosion of science funding. However transient this economic trend may turn out to be, there is an acute realization in Japan that drastic changes in the country's conservative philosophy and social structure have to occur in order for the country to become a leading and respected member of the modern world community.

I have been a bitter critic of the Japanese system, but I'm encouraged by these changes. In many cases, the U.S. and Japan represent two policy extremes, and each could benefit by adopting some of the other's programs.

I am grateful to my five colleagues who contributed their informative essays on short notice. I thank, as well, Kenji Mori of the University of Tokyo for bringing the Japanese Science Council questionnaire results to my attention; as a JSC member, he was heavily involved in the project. I am also grateful to other colleagues who have provided me with updated information. □

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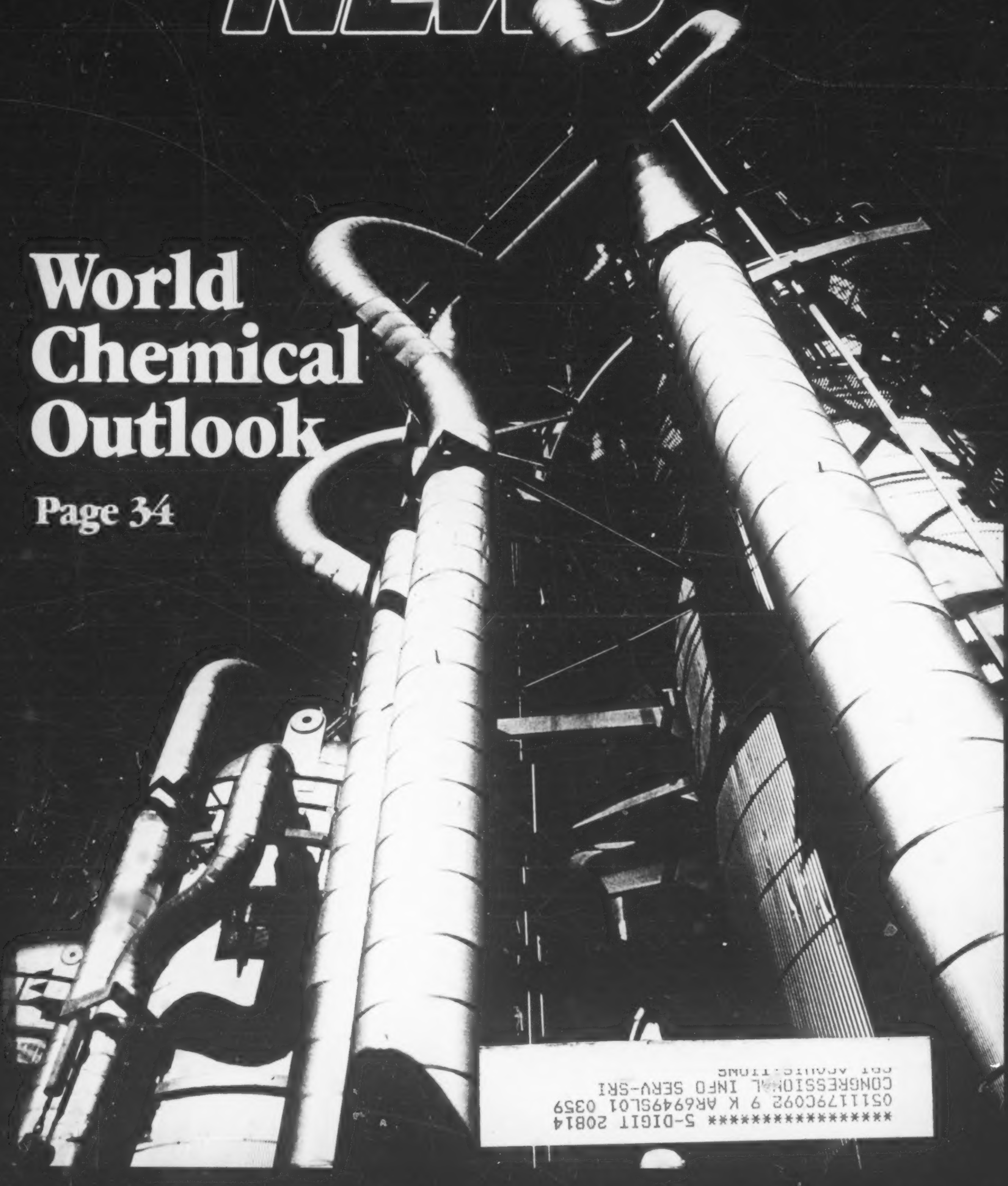
DECEMBER 9, 1991
CHEMICAL & ENGINEERING
NEWS



World Chemical Outlook

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Volume 69, Number 49
CENEAR 69 (49) 1–76
ISSN 0009-2347

CHEMICAL & ENGINEERING
NEWS
DECEMBER 9, 1991

News of the Week

- **National Academy of Sciences panel assesses future of U.S. research universities, finds heyday of science is over.** Page 4
- **Three environmental groups petition EPA to speed up phaseout of ozone-depleting CFCs and halons.** Page 5
- **Citing divergent business strategies, Solvay and Laporte plan to divide their joint interests in the Interox Group.** Page 5
- **OSHA issues standard designed to protect lab and health care workers against exposure to blood-borne pathogens such as hepatitis and AIDS viruses.** Page 6
- **International group of scientists drafts recommendations aimed at identifying the scientific knowledge base needed for environmental policy decisions in coming decades.** Page 6

Cover: Occidental Chemical's ethylene oxide reactors at Bayport, Tex., petrochemical plant

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Business

Venture capital for specialty chemicals, materials firms is hard to find in current weak economy. **Page 11**

Government

Suggestions for controlling indirect costs of research got cool reception from NIH advisory panel. **Page 18**

Science/Technology

Mass spectrometry technique based on chemical reactions between molecular ion beams and surfaces could benefit surface, molecular structure analyses. **Page 22**

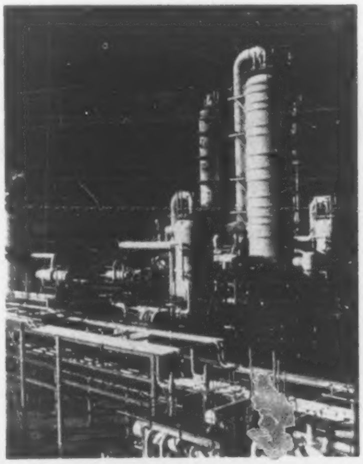
U.S., Soviet scientists hail performance of joint space project to map total ozone content in Earth's atmosphere. **Page 24**

Pressure-sensitive paint that continuously maps surface pressure on airplanes uses phosphorescent porphyrin indicator. **Page 29**

Henkel Corp.'s fellowships for two doctoral candidates in colloid and surface chemistry are available again in 1992. **Page 30**

Education

Soviet-American workshop on teaching high school chemistry, held recently in Moscow, focused on ChemCom—ACS's curriculum for students not planning science careers. **Page 32**



World Chemical Outlook

The recession that has gripped many economies around the globe, and the chemical industry as well, is showing signs of abating, although it will be well into next year before the industry climbs back to profits and profitability growth. **Page 34**

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LETTERS

Forms of carbon

The situation with regard to the number of distinct forms of carbon is more complex than noted by James Intrater (C&EN, Nov. 4, page 5). Since 1975, the carbon societies of the U.S., U.K., France, Germany, and Japan have collaborated to define the various forms of this unique element and agree on their nomenclature.

The recommendations of the International Committee for Characterization and Terminology of Carbon have been published periodically in the journal *Carbon* [**13**, 251 (1975); **20**, 445 (1982); **21**, 517 (1983); **23**, 601 (1985); and **27**, 305 (1989)]. Currently, the list comprises some 73 forms of carbon but does not yet include the new fullerene family, linear carbyne forms, or the more controversial "chaoite."

Douglas W. McKee
Chairman, American Carbon Society
Schenectady, N.Y.

Describing chemicals' use

This is in response to the Newscripts item (C&EN, Sept. 30, page 84) on the euphemism of the year. Sidney Toby implies that the Conrail spokesman was misleading the public by referring to butane "as a light, nontoxic hydrocarbon which is commonly used for cigarette lighter fuel." Further, he says that this is analogous to calling dynamite "a relatively nontoxic material used as a labor-saving device in the mining industry."

This belief is unjustified. The statement by the Conrail spokesman gives all of the relevant information. How many people do not know that fuel burns? Certainly, the Conrail spokesman could have referred to butane as highly flammable, but does that really serve a purpose? In fact, the Conrail statement gives more information to the public than the standard description of butane a chemist would give. Namely, it gives butane's use.

The American public generally believes that industry—the chemical industry in particular—is involved in the widespread manufacture and transportation of hazardous chemicals with little or no useful purpose. It is in everyone's best interest if the chemicals are more closely associated with their end use in the public's mind. What is wrong with describing dynamite as "an explosive used in the mining and construction industry"? This is a more appropriate analogy.

By placing the letter in the Newscripts section, C&EN implies agreement with his letter. As we all know, this page is usually reserved for inane number games, misprints, and statements by public officials who believe pencils cause lead poisoning. It is ironic that this occurs in the same issue as the article on Dexter Baker, Air Products' chief executive officer. He points to a public perception that puts "toxic" in front of the word chemical and a desire by the Environmental Protection Agency "to limit phenol discharges to concentrations as low as 21µg per L" while the Food & Drug Administration allows phenol concentrations up to 1.4% in sore-throat medication. Perhaps if references to phenol included "used as an anesthetic in sore-throat preparations" we would not get such schizophrenic policies.

Alex Perkins
Marietta, Ga.

Microscale chemistry

The gentlemen from the chemistry department at Merrimack College are to be commended for their discussion of the advantages of microscale chemistry and for relating some of the history (C&EN, Nov. 4, page 5). This letter will add to that history.

In 1946 some 18 university presidents in the state of New York, as a board of trustees, established the Associated Colleges of Upper New York (ACUNY), as suggested by then-Gov. Dewey, to provide college places for returning G.I.s.

Notice to members wishing to resign

ACS members who wish to resign their membership at the end of 1991 should do so now by letter to the ACS executive director. Bylaws specify that anyone who fails to resign by Dec. 31 will be carried on the rolls in 1992 as a member and will be responsible for dues. Failure to pay dues does not constitute a resignation.

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World Chemical Outlook

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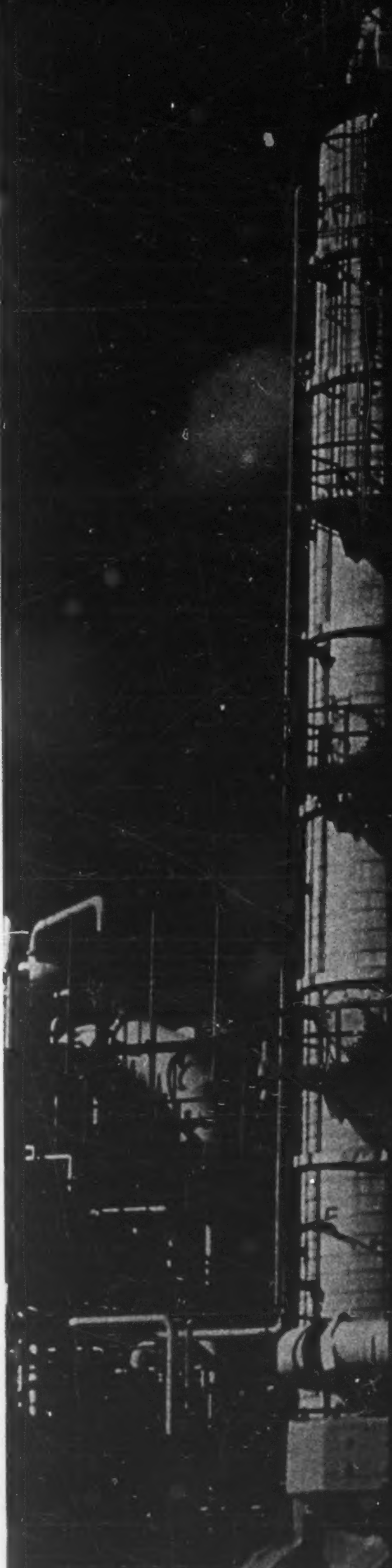
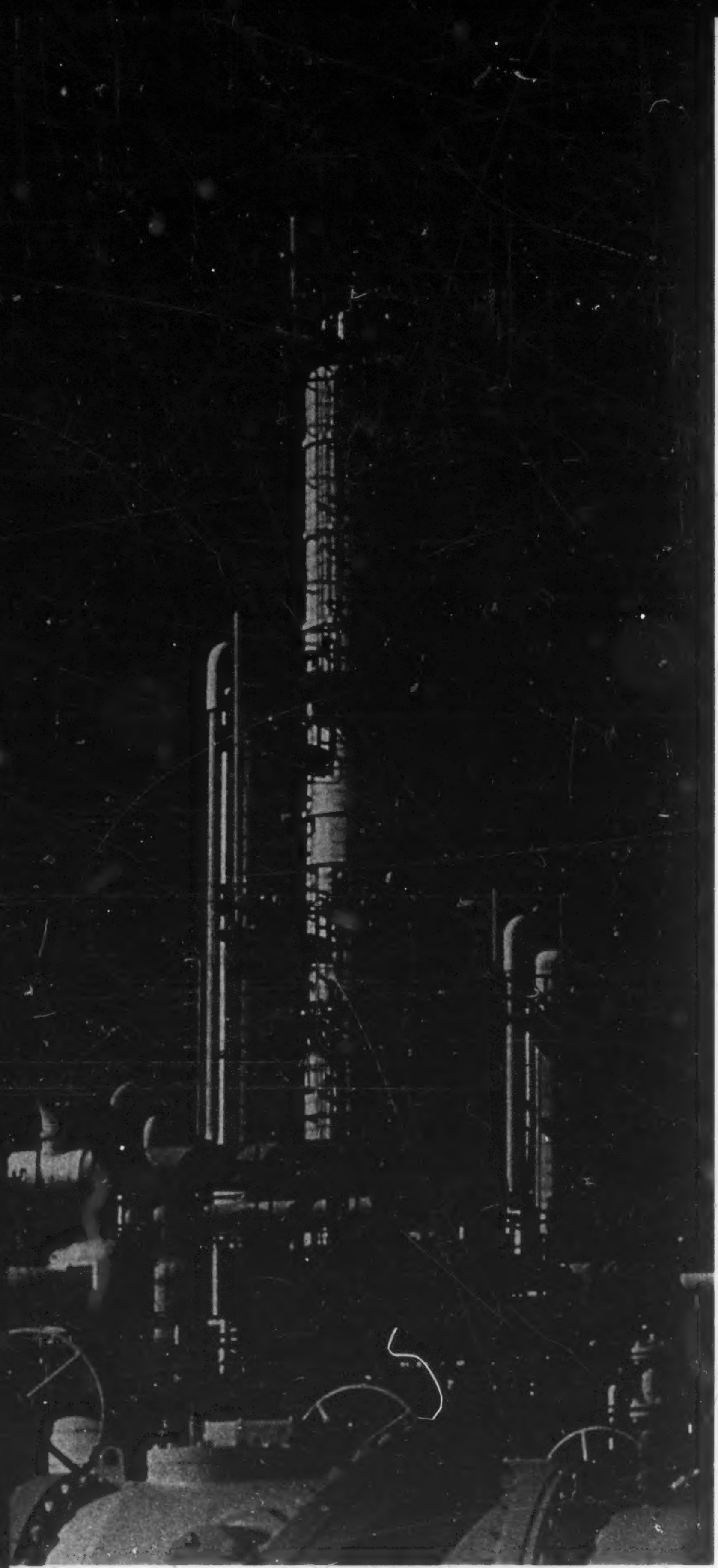
The recession that has held various world economies—and the world chemical industry—in thrall for the past year may well be just about history. A number of signs point to this view.

However, the end of any economic slowdown takes time to translate itself to the chemical industry. In Canada and the U.S., the recession is just about over, although it will be sometime in 1992 before the chemical industry begins to see a return to profit and profitability growth. Europe is a little further behind, but again, 1992 probably will bring slightly improved results. Japan, on the other hand, seems to be still in the early stages of slowdown, and it has a period of yet slower growth in its future.

In 1991, foreign trade has played a key part in the fortunes of the chemical industry. In the U.S., record





trade has buoyed shipments, helping prevent a much greater downturn. In other countries, however, the reverse has been true. Imports into these countries from the U.S. have had some adverse effects on their chemical industries. And producers, especially in Canada and Europe, are waiting for an upturn in U.S. domestic demand to pull these products out of the international marketplace.

Some realignment and restructuring of the industry also took place in 1991, with rationalization of plants, acquisitions and divestitures of businesses, and downsizing of work forces—a trend likely to continue throughout next year.

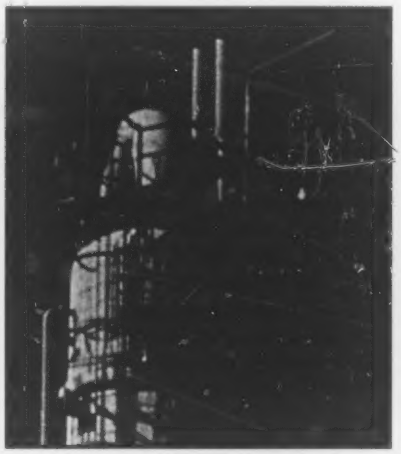
In short, 1992 promises to be a year of rebuilding for the worldwide chemical industry. It will be a year for rebuilding markets and thus sales, earnings, and profitability.

UNITED STATES

Better times ahead for chemical industry

Growth in 1992 will be slow, however, as fortunes of chemical producers lag moderately better economy

William J. Storck
C&EN Northeast News Bureau



For the past year the U.S. chemical industry has been throttled by recession, but the end may be in sight. Certainly sales are flat for the industry, and sure, earnings are down considerably from last year and the year before. Yes, profitability has taken it on the chin for the past year and a half. But by the second quarter of 1992, the industry may be looking at a better marketplace as the U.S. economy and various world outlets for its products start to improve.

The signs are there that the current recession has about run its course. Some of these indications are economic and some are psychological, but taken together they point to an upturn in the near future. Granted, the expansion that is coming will not be rapid, but rather will be the slow recovery that some people have said will have the profile of a dinner plate rather than a soup bowl or a teacup.

Taking first the most cynical, but often the most accurate, reason for the view that the recession is nearing an end: In Washington, Congress is getting into the act. Legislators, who in the past few months have learned that unemployment has risen in their home districts, are calling for economic stimulation by the executive branch. Historically, this has meant that an economic slowdown is about over. When those Senators and Representatives begin to introduce economic legislation, one can be sure the end of the recession is at hand, if not already past.

Also, chemical companies have begun a round of restructurings and reductions in force. Again, this is usually a lagging indicator as companies take time to make their plans. Big restructurings have taken place at such large chemical producers as Du Pont, Union Carbide, W. R. Grace, and Hercules as they move to trim costs and improve productivity.

In New York City, the strength of the stock market appears to bode well for the economy. Some recent precipitous declines in the market have been followed almost immediately by recoveries and renewed growth, showing an underlying strength, according to market analysts. If the market is assumed to be an efficient leading economic indicator, then this would signal a modest recovery beginning some time before the second half of 1992.

In fact, many economists are saying the recession in the U.S. is already at an end. These pundits say that, although gross national product declined in the second quarter, by the end of that three-month period, economic activity had already picked up slightly. And they believe this growth has continued through the rest of this year.

The Commerce Department also holds that view. In its earliest advance forecast of third-quarter growth in the gross national product, the Bureau of Economic Analysis predicted that constant-dollar GNP in the third quarter would be up about 0.6% from the previous three months, more than recovering the ground lost between the first and second quarters. Unfortunately, C&EN went to press immediately before the government's preliminary estimate of GNP growth was made public, so that at the time this was written, it could not be confirmed that growth did indeed take place in the third quarter.

Be that as it may, most economists are saying the end of the recession is at hand, but growth in 1992 will be lackluster. Donald H. Straszheim, chief economist at Merrill Lynch, for example, says, "Distinctly sub-par growth can be expected during 1992."

Any upturn in the economy will prove a boon for the chemical industry, but it will not see the growth rates prevalent in the late 1980s. And the chemical industry probably will lag the general economy in turning around. Indeed, if the economists are correct and the recession did end in the third quarter, then it is readily apparent from a number of indicators that chemicals are lagging. Working against a rapid upturn are a number of factors, including still weak major end-use markets. Chief among these are construction and automobiles.

Commercial construction is very weak and will continue to be so for some time as vacancy rates in office buildings remain high across the country. However, there are some hopeful signs in the residential market. While new home building continues in the doldrums, for the most part, in the U.S., resales of existing homes may be starting to move upward. In October, sales of existing homes, according to government data, increased 1% from the previous month, and were up about 2.6% from the same month in 1990 as buyers responded to the lowest mortgage rates in more than a decade.

Although this may presage an increase in new home construction and indicate that the new lower interest rates are indeed having an effect, it is also important for the chemical industry in that home buyers will want to refurbish those recently purchased houses, requiring such downstream chemical products as paints and carpeting.

The auto industry, on the other hand, seems to be chronically ill. Perhaps, at some time, lower interest rates will help spur some growth in sales, but as yet there is no indication of an upturn. Throughout the year, sales of domestically produced automobiles have been weak. In the latest reporting period of mid-November, sales of U.S.-produced cars and trucks were down almost 20% from the same period last year. This will hold down demand growth for a number of chemical products, including plastics, synthetic elastomers, and fibers.

The constraints on demand during the past year have had a number of deleterious effects on the chemical industry, including lower capacity utilization and prices. Although preliminary estimates of seasonally adjusted capacity use in the chemical industry rose slightly in October to 79.6%, it is still below the 81% measured a year earlier. Soft demand is not the only culprit here, but rather is working in combination with increased capacity from new plants, particularly in the petrochemicals segment. Some petrochemicals capacity still is expected to come on stream in the near future, thus almost guaranteeing that capacity use is not going to rebound as much as the industry would like through 1992.

Low capacity use ensures price pressure, and 1991 has proved to be no exception to this rule. Chemical producers have seen prices languishing throughout most of the year. Average prices through the first three quarters of 1991 were higher than the comparable 1990 period, but there was a price runup in the latter part of 1990 that continued into early 1991 and then abated. This came about because of fears of shortage resulting from the military buildup and impending war in the Middle East. Once these fears subsided, prices slid.

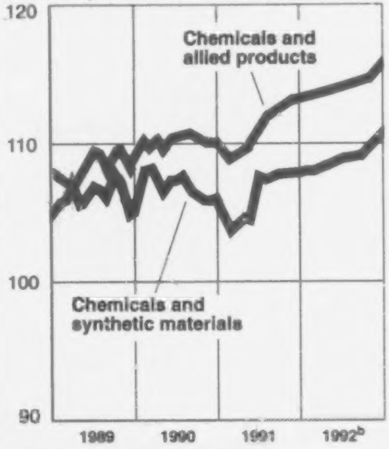
Thus the government's producer price index for chemicals and allied products through the first nine months averaged almost 3% higher than the same period last year. But the index in September was more than 3% below its value at the beginning of 1991.

For the major subcategory of industrial chemicals, price problems were even worse. The producer price index for the first nine months averaged nearly 1% above the comparable 1990 period. However, the downward trend throughout this year put September's index almost 7% below January's value.

Producers say this downward trend may well be reversing. Indeed, October price indexes reported by the government for both chemicals and allied products and industrial chemicals were higher than the previous month's. But until excess capacity is worked off, chemical makers are going to find it hard to do much more than pass along cost increases.

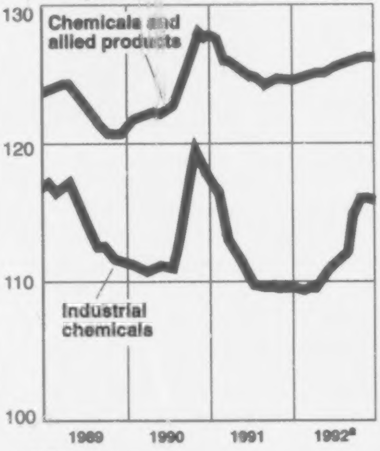
Chemical producers have been

Higher demand will spur chemical production . . .



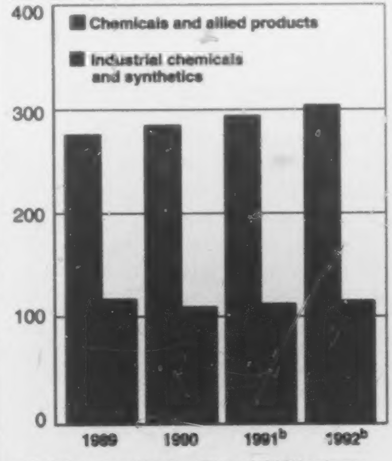
a Seasonally adjusted. b C&EN estimates.
Source: Federal Reserve Board

. . . and prices will begin to turn back up . . .



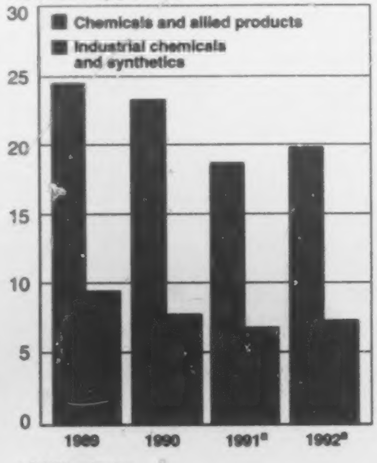
a C&EN estimates.
Source: Bureau of Labor Statistics

. . . bringing slight improvement to sales . . .



a Excludes sales of foreign affiliates. b C&EN estimates.
Source: Bureau of the Census

. . . and starting profits on the road back



a C&EN estimates.
Source: Bureau of the Census

CIRCLE 5 ON READER SERVICE CARD →

somewhat fortunate this year in that raw material costs, by and large, charted the same pattern as did selling prices—high at the beginning of the year and falling throughout the remainder. And there may be an opportunity here for producers in the near future if they can indeed raise selling prices. There is speculation by oil analysts that OPEC (the Organization of Petroleum Exporting Countries) will not soon return to production quotas for its members. This could mean a glut of oil by next spring and further lower raw material costs for chemical producers, giving them better profit margins, even in a lackluster pricing arena.

On the demand side, the chemical industry has held up fairly well through 1991, but there are some worrisome signs that demand could be weaker than the simple numbers show. Chief among these is exports and their effect on total demand.

According to government figures, the value of shipments of chemicals and allied products through the first nine months of this year totaled $218 billion, an increase of 1.8% over the same period last year. Meanwhile, industrial chemicals were weaker, with the value of shipments dropping about 1.2% to $116 billion. If the values for these two categories are deflated using their respective producer price indexes to get a rough estimate of physical volume, then chemicals and allied products declined about 2.5% in poundage and industrial chemicals declined about 2.0%. This is not bad in terms of demand in relation to the slow economy, but if the record exports are subtracted from these shipments, it means that domestic demand is certainly much weaker than is first apparent.

A good example is plastics. Using data from the Society of the Plastics Industry's Committee on Resin Statistics, shipments of the major thermoplastics—low-density, linear low-density, and high-density polyethylene; polypropylene; polystyrene; and polyvinyl chloride—in the first three quarters of 1991 totaled about 32.9 billion lb, up 1.2% from the corresponding period last year. During the same period, exports of these thermoplastics rose 45% to 4.73 billion lb. Thus, exports as a percentage of shipments have risen to about 14% through the first nine months from about 10% in the first three quarters of last year.

And if exports had held flat in 1991 from 1990, instead of rising 45%, the shipments would have been down 3.3% instead of being up a little more than 1%.

Slow recovery next year could force the industry to continue to restructure. Chemical industry employment is down about 5000 workers since the beginning of the year, and because many of the reductions in force that have been announced will not be complete until next year, employment likely will continue to head down.

In any restructuring, there also is the possibility of shifts in alignment of the industry through sales and purchases of businesses or divisions or through mergers. Thus far, little of this seems to be going on, at least above the $100 million level. And if industry sources are correct, this activity may not pick up. They say that there is plenty for sale, but the asking price is just too high.

Thus, by the end of next year, the U.S. will be looking at an industry much as it is today in terms of the players, but slightly better off in its economics with improved demand, operating rates, pricing, and, thus, profitability. □

U.S. production of most major chemicals is down, but recovery will begin next year

	1989	1990	1991	1992
INORGANIC CHEMICALS				
Thousands of tons unless otherwise indicated				
Ammonia	16,467	16,795	17,214	17,558
Chlorine gas	11,413	11,809	11,573	11,689
Hydrochloric acid	3,177	3,013	2,712	2,847
Nitric acid	8,349	8,000	7,400	7,480
Oxygen, billions of cu ft	461	462	465	471
Phosphoric acid	11,737	12,035	12,396	12,700
Sodium hydroxide	10,492	12,030	12,210	12,576
Sulfuric acid	43,301	44,044	44,250	44,803
ORGANIC CHEMICALS				
Millions of lb unless otherwise indicated				
Acetic acid	3,294	3,755	3,717	3,760
Acetone	2,524	2,221	1,800	1,872
Acrylonitrile	2,362	3,029	2,666	2,810
Benzene,[a] millions of gal	1,631	1,615	1,600	1,620
Butadiene	3,121	3,155	3,045	3,118
Caprolactam	1,307	1,379	1,296	1,321
Cumene	4,426	4,311	4,310	4,482
Cyclohexane	2,273	2,467	2,344	2,410
Ethylene	34,988	37,474	39,725	40,718
Ethylene glycol	5,461	5,027	5,278	5,440
Formaldehyde	5,893	6,412	5,963	5,903
Methanol	8,167	7,986	8,784	8,881
Phenol	3,806	3,512	2,915	3,031
Phthalic anhydride	917	941	866	912
Propylene	20,571	22,133	22,686	23,139
Styrene	8,337	8,017	7,295	7,477
***o*-Xylene**	983	943	980	990
***p*-Xylene**	5,344	5,200	5,408	5,450
PLASTICS				
Millions of lb				
Polyethylene, high density	8,102	8,334	8,750	9,013
Polyethylene, low density	9,695	11,176	11,567	11,856
Polypropylene	7,238	8,318	8,464	8,480
Polystyrene	5,104	5,012	4,761	4,860
Polyvinyl chloride	8,478	9,088	9,090	9,170
SYNTHETIC FIBERS				
Millions of lb				
Acrylic and modacrylic	543	506	455	473
Nylon	2,740	2,662	2,491	2,495
Olefin and vinyon	1,639	1,822	1,786	1,821
Polyester	3,594	3,195	3,339	3,456

a Petroleum refiners only. **Sources:** Bureau of the Census, International Trade Commission, Society of the Plastics Industry's Committee on Resin Statistics, Fiber Economics Bureau, C&EN estimates (for 1991 and 1992)

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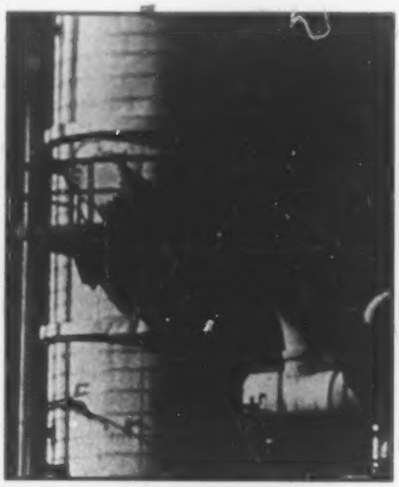
FOREIGN TRADE

U.S. chemical trade enjoys record surplus

Chemical industry scores big in exports and at Uruguay round of international trade talks

Earl V. Anderson
C&EN Northeast News Bureau



The overall U.S. trade deficit will shrink below the $100 billion level this year for the first time since 1983. For this, a lot of the credit goes to the chemical industry.

U.S. chemical companies will chalk up an amazing trade surplus of close to $20 billion in 1991 on the strength of exports that will top $40 billion for the first time. This year's enviable chemical trade surplus will, of course, be a new record—the third consecutive record that the industry has set.

Meanwhile, the industry's trade representatives–are also making progress on the political front. They and their counterparts in Europe and Canada have come up with a joint plan to cut chemical tariffs in the still-unfinished Uruguay round of multilateral trade negotiations. Their chemical tariff-cutting proposal is one of the few bright spots in the long and difficult trade talks.

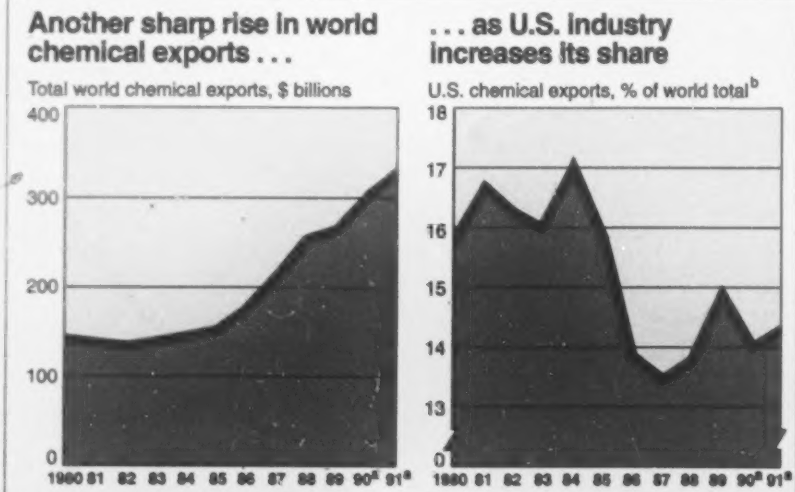
U.S., European Community (EC), and Canadian negotiatiors at the trade negotiations already have begun pushing this joint proposal on chemical tariffs. Developed by the Chemical Manufacturers Association, the European Chemical Industry Council, and the Canadian Chemical Producers' Association, the proposal basically agrees in principle with an earlier U.S. proposal in July 1991 to harmonize chemical tariffs at lower than current levels. That proposal called for the "global harmonization" of chemical tariffs by the world's largest chemical-producing countries.

The new proposal also advocates global harmonization of chemical tariffs. But it has two caveats. First, it must receive broad country support. That is, many other countries in addition to the "largest chemical producers" must agree to it. These other countries include not only industrialized nations, but also some newly industrial nations and developing countries as well.

In fact, says one U.S. chemical trade expert, the three chemical groups that developed the chemical tariff proposal have in mind a specific list of 21 countries that are members of the General Agreement on Tariffs & Trade (GATT). The Uruguay round is being held under the auspices of GATT.

The obvious large chemical producers—the U.S., the 12 member countries of the EC, Japan, Canada, and Switzerland—are on the list. So, too, are eight developing nations (including Brazil, India, and Mexico), and two newly industrialized countries—South Korea and Singapore. If these countries—or at least most of them—do not support the chemical tariff proposal, presumably the three chemical groups that originated it will withdraw their support.

The second caveat involves linking chemical tariff cuts to reducing or eliminating nontariff measures. From the time the Uruguay round started in 1986, representatives of the U.S. chemical industry have been telling U.S. trade officials that they will not support the trade negotiations if they degenerate into a simple tariff-cutting exercise.



Another sharp rise in world chemical exports . . .

. . . as U.S. industry increases its share

a C&EN estimates. b Defined as U.S. chemical exports as percentage of world chemical exports less U.S. chemical imports.
Sources: United Nations, Organization for Economic Cooperation & Development, European Community, Japanese Ministry of International Trade & Industry, Bureau of the Census

Plastics lead a surge in chemical exports

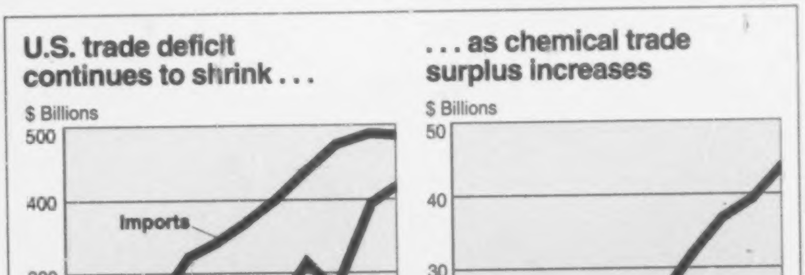
$ Millions	U.S. chemical exports 1991[a]	1990	1989	1988	U.S. chemical imports 1991[a]	1990	1989	1988
Organic chemicals	$11,449	$10,400	$10,609	$ 9,704	$ 8,341	$ 7,392	$ 7,042	$ 7,250
Plastics in primary form	7,735	6,428	5,727	5,503	1,912	1,974	1,687	1,373
Medicinals and pharmaceuticals	4,632	4,103	3,660	3,362	2,964	2,500	2,086	1,849
Inorganic chemicals	4,108	3,816	4,319	4,289	3,107	3,234	3,231	3,147
Fertilizers[b]	3,015	2,574	2,821	1,199	932	955	999	991
Plastics in nonprimary form	2,753	2,633	2,202	2,001	1,816	1,774	1,629	1,574
Essential oils, toilet, and polishing materials	2,272	1,963	1,469	1,126	1,362	1,323	1,165	1,175
Dyeing, tanning, and coloring materials	1,617	1,588	1,097	1,100	1,362	1,288	1,133	1,302
Other	6,119	5,478	4,583	3,725	2,104	2,028	1,780	1,665
TOTAL	$43,700	$38,983	$36,485	$31,909	$23,900	$22,468	$20,752	$20,326

a C&EN estimates. b Except crude of group 272. **Source:** Bureau of the Census

If tariffs are to be cut, the U.S. chemical industry also wants negotiators to dismantle many of the nontariff measures that keep its exports out of foreign markets. That linkage between tariffs and nontariff measures is also part of the tripartite chemical tariff proposal.

If these caveats are met, and if the negotiators at the trade negotiations ultimately reach agreement, worldwide chemical tariffs will drop considerably from current levels.

The proposal calls for present chemical tariffs of 10% or less to be cut to a level of 5.5% or 6.5% over five years, depending upon product category. Tariffs between 10 and 25% will fall to 5.5% over 10 years, while tariffs greater than 25% will drop to 6.5% over 15 years.



a C&EN estimates. **Source:** Bureau of the Census

Tariffs that already are less than the proposed harmonization levels will remain as they are. However, the three chemical groups say that reducing tariffs below the proposed harmonization levels, including completely eliminating tariffs, is a "viable goal."

In fact, pharmaceuticals already have been proposed for so-called zero for zero treatment in the trade talks. That is, one country agrees to eliminate its duties on pharmaceuticals if other countries agree to do the same.

The U.S. pharmaceutical industry supports this concept. And proposals for similar zero for zero tariff treatment are being worked up for cosmetics, toiletries, soaps and detergents, and some fertilizers.

The tripartite tariff proposal covers all of the products in the chemical sections—chapters 28 through 39—of the Harmonized Tariff Schedule. There are no exceptions. Every product in these 12 chapters will be treated in one of three ways: Their tariffs will be cut to the proposed harmonization level; they will be treated under the zero for zero concept; or they will be treated as "import-sensitive" products.

To qualify as an import-sensitive product, producers must justify their claims to the trade negotiators of their respective countries. Only then may the harmonization level be different than the proposed 5.5% or 6.5% levels. However, even for import-sensitive chemicals, tariffs can be cut no less than 30%, and the phase-in period cannot be more than 15 years.

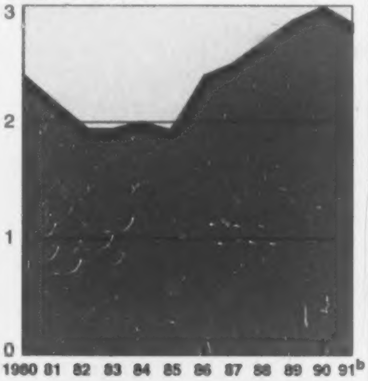
Trade negotiators, still under the gun to come up with a trade agreement almost a year after the trade talks collapsed last December, no doubt see this comprehensive, joint tariff proposal by three of the world's influential chemical trade associations as a breath of fresh air. However, they will need much more than this one, narrowly focused tariff proposal to succeed.

They have made some progress in the contentious agricultural trade negotiations, but much still remains to be done on this difficult issue. The Uruguay round also includes, among other things, negotiations on trade in services, intellectual property rights, and foreign investment.

When the trade negotiations were

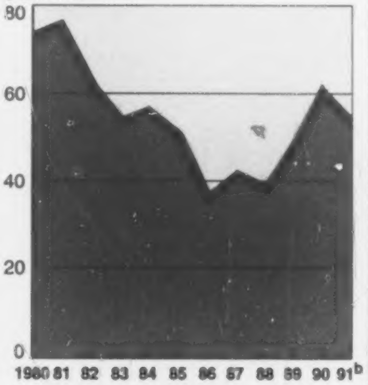
U.S. oil imports will slip this year . . .

Billions of barrels[a]



. . . pushing down the oil import bill

$ Billions[a]



a All petroleum products. b C&EN estimates.
Source: Bureau of the Census

launched in 1986 in Uruguay, the U.S. chemical industry said it was concerned about four major issues: market access (including tariffs), intellectual property, investment, and subsidies. The tripartite proposal takes care of the market access concerns. Of the remaining three, at press time only a proposed intellectual property agreement looked as if it would be acceptable to U.S. chemical industry trade experts. They are not very happy about either the subsidy or investment proposals made so far.

The big question for the industry, then, is where to draw the line on what will be an acceptable trade package deal. The industry never said it would withdraw its support for a total Uruguay round agreement if it disliked, say, only one or two of the agreements it considers important. But, until top-level negotiators start making some tough political decisions, the industry's trade policy decisionmakers won't be able to answer that question or draw that line.

Meanwhile, the U.S. chemical industry can bask in the limelight of its performance on the world trade marketplace. Chemical exports this year will amount to an estimated $43.7 billion, up a healthy 12% over 1990.

Coupled with chemical imports that grew at only about half that rate—up 6.4% to $23.9 billion— that exceptional export performance gives the U.S. chemical industry a hefty $19.8 billion trade surplus for the year. That's more than $3 billion higher than last year's chemical trade surplus, itself a record at the time. And it pushes chemicals ahead of aircraft as the U.S. industry with the largest trade surplus.

Why the exceptional increase in chemical exports this year? It's difficult to credit any one thing. It's more a combination of factors. For instance, the weak economy in the U.S. put a lid on domestic chemical demand. This meant more chemical capacity available to produce products for the export market. And, compared with the U.S. economy, the economies—and hence demand—in those export markets held up fairly well.

The dollar exchange rate against the major foreign currencies fluctuated widely this year. It was a mixed blessing. Normally a weak dollar helps exports by making them less expensive in foreign markets. A strong dollar makes exports more expensive; hence, less competitive overseas. But with the dollar vacillating between strength and weakness against the other major currencies, it probably had little impact on U.S. chemical trade.

Whatever the reason, U.S. chemical exports, paced by strong increases in organics, plastics, fertilizers, and medicinals, have helped put a big dent in the country's troublesome trade deficit. U.S. exports of all products this year increased more than 6% to about $420 billion. Meanwhile, imports declined for the first time since 1982, ending the year 2% lower than last year at $485 billion, thanks in large part to a lower oil import bill.

Those higher exports and lower imports shaved $36 billion off last year's trade deficit. At about $65 billion, the trade deficit has not been that low since 1983. ◻

U.S. trade deficit slips below three digits

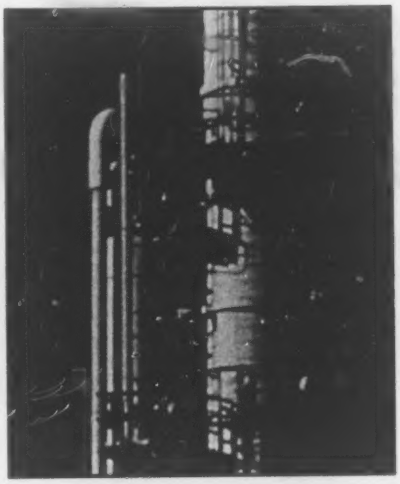
	U.S. exports				U.S. imports			
$ Billions	1991[a]	1990	1989	1988	1991[a]	1990	1989	1988
Machinery and transport equipment	$185.8	$172.5	$148.8	$135.1	$208.2	$208.0	$205.6	$197.0
Chemicals	43.7	39.0	36.5	31.9	23.9	22.5	20.8	20.3
Miscellaneous manufactures	42.9	39.3	32.6	24.5	81.6	81.5	76.5	70.4
Manufactured goods classified by material	36.2	31.7	27.2	22.8	58.3	59.9	62.0	61.5
Food and live animals	29.0	29.3	29.7	26.4	22.3	21.9	20.6	20.1
Crude materials, inedible except fuels	25.7	27.0	26.9	25.1	13.1	14.5	15.4	13.4
Mineral fuels and lubricants	11.8	12.2	9.9	8.2	55.8	64.5	52.5	41.1
Beverages and tobacco	6.7	7.1	5.5	4.5	4.4	4.6	4.4	4.1
Animal and vegetable oils, fats, and waxes	0.8	1.2	1.4	1.5	0.5	0.8	0.7	0.8
All other products	16.8	16.2	31.2	27.5	17.0	16.8	14.4	12.6
TOTAL	$420.0[b]	$394.6[b]	$364.3[b]	$322.4[b]	$485.0	$495.0	$472.9	$440.9

a C&EN estimates. b Includes reexported imports not included in individual categories. **Source:** Bureau of the Census

Recession woes to continue for chemicals

Major factors have been Persian Gulf War, inventory trimming, overcapacity; no turnaround seen till mid-1992

Patricia L. Layman, C&EN London



For the Western European chemical industry, 1991 has been the year in which the light at the end of the tunnel flickered and went out. And there seems to be little likelihood it will be rekindled until at least the middle of next year.

At the end of last year, when the industry had come down with a bang from two frothy years of good times and high profits, predictions were that the downturn would have worked itself out by the second half of 1991. Came the second half, however, and after a brief flash of hope, the picture became gloomily clear: Downturn became full-fledged recession, spreading slowly across the continent.

Marketing managers around the European chemical industry say the major factors influencing the European chemical industry in 1991 were the Persian Gulf War, subsequent trimming of inventories, overcapacity, and the general economic recession. The initial reaction to developments in the Middle East in 1990 was to increase inventory levels as a cushion against possible raw material shortages brought on by the conflict. In the early part of 1991, this trend was reversed, and drastic cutting of inventories exacerbated a general drop in demand caused by the economic recession. The icing on the cake: The price of naphtha feedstocks remained stubbornly high, squeezing producers' price-cost margins.

Tony Church, chemicals analyst with stockbrokers Wertheim Schroder in London, says, "I thought by August and September, the industry had found the bottom. I was wrong. The petrochemicals business now faces nine months of losses." Even downstream producers were not immune, he says. "Producers of high-value-added materials were disappointed as well. They forgot that if you are selling to the motor vehicles industry, and that industry is down 40%, you are down 40%."

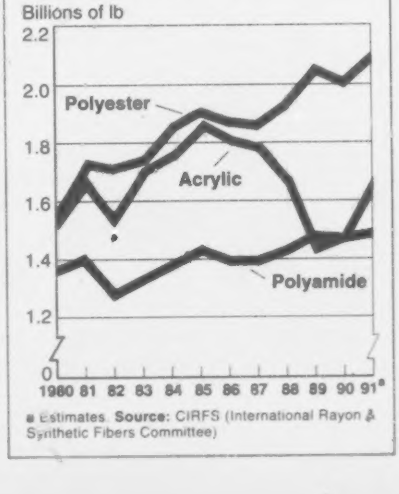
On a country-by-country basis, there clearly have been differences in performance during the year. Spurred by demand from unification, Germany had been growing strongly. On the other hand, in the U.K. growth rates slowed down substantially—but not into the red.

Similarly, some companies have been able to protect themselves from the worst effects of the downturn. Companies with significant emphasis on noncyclical products, for example, such as Bayer in Germany and Akzo in the Netherlands, have been able to limit the damage caused by the general economic conditions.

Church believes petrochemicals look very bad because they came off a high in 1988, 1989, and 1990. By the time the war in the Persian Gulf was over, demand remained high to some extent, but the problem had become one of overcapacity and supply. The result has been, among other things, that prices have been less than costs.

Without a major upturn in demand in the European market, the only answer he sees is that producers have to cut capacity, a move he sees no signs of, "although logic says they will eventually have to." Additionally, if the economy in the U.S. picks up, the extra demand there will divert the U.S.-produced material now being sold in Europe, removing some pressure on pricing.

There is not much likelihood of an immediate upturn in European economies, however, says Richard D. Freeman, corporate chief economist with ICI. Speaking to chemical market researchers at the ECMRA meeting in London in October, Freeman pointed out that after several years of strong growth of real gross domestic product in many countries, their economies turned down around mid-1990, and the deceleration gathered pace in the first half of this year. With the main exception of Germany, demand and activity in Europe now seem to be strengthening again, although any recovery is rather weak and drawn out.

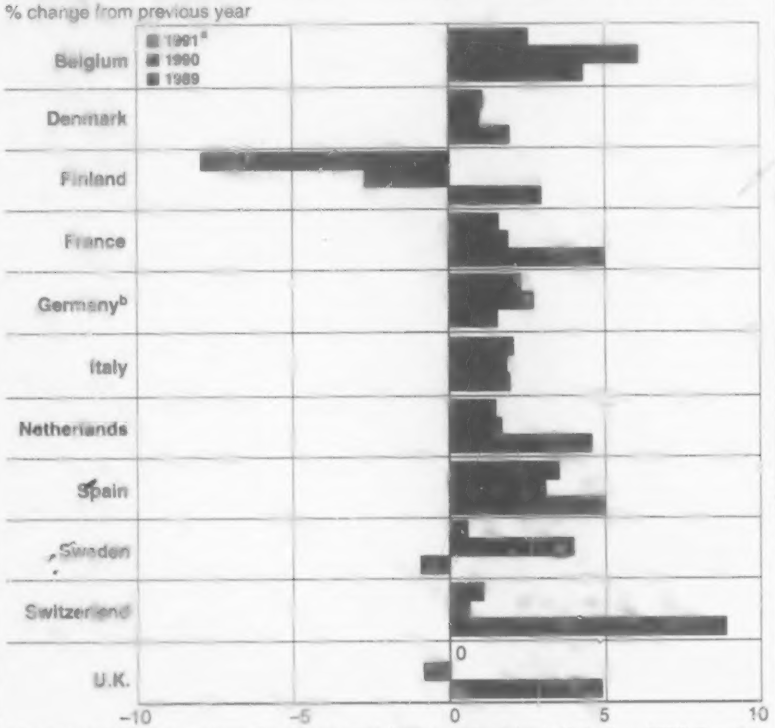


Man-made fiber production edges up in 1991

a Estimates. **Source:** CIRFS (International Rayon & Synthetic Fibers Committee)

Production slows for most of European chemical industry

% change from previous year



a Estimate. b Does not include former East German states. Sources: National chemical federations, CEFIC (European Chemical Industry Council), C&EN estimates

This year, with the collapse of consumer and business confidence, investment has virtually come to a stop in the major European economies and in many of the smaller countries, and most severely in the U.K. The relatively weak position of corporate finances has been compounded in 1990 and 1991 by falling profitability. And now, even in Germany, investment is slowing down sharply.

Capital spending in the chemical industry has been trimmed somewhat—frequently mentioned is a rate of about 10%—or is just barely holding its own. There are very few examples of investment being significantly increased, unless a company has been in the midst of a major project it couldn't handily stop.

Considering these factors, chemical production in Western Europe probably will end the year about 0.5 to 1% higher than in 1990, rather than the 1.5% forecast in the first half of the year by CEFIC, the European Chemical Industry Council. The slow revival of sales and a rebuilding of stocks anticipated in the second half of the year never came through.

Neither did a general strengthening of prices come about. Companies

Chemical economies remain unsettled for Eastern Europe

At the October meeting of ECMRA, the European marketing research group, in London, Richard D. Freeman, corporate chief economist at ICI, told chemical marketing researchers what most of them already knew—that the economies of Eastern Europe are in a sad state.

Last year, for example, gross domestic product for the region fell 4.5%. This year, the drop officially is 5%, with predictions of further drops of 6% in 1992 and 4% in 1993. Not until 1994 will some sort of stability take hold, he says. However, those predictions understate the fall in activity, particularly in view of recent events in the Soviet Union. "The main messages are that the economies are very depressed and that output is expected to fall for the next two or three years at least," he adds.

That, in turn, has had a direct impact on Western European chemical companies. For example, Bryan K. Sanderson, chief executive officer of BP Chemicals, says the company's sales in Eastern Europe have been running at about $20 million per year in the past few years. The U.S.S.R. accounted for about one third of that, but its portion is down 50% this year.

In the Soviet Union, by one estimate, industrial production likely has fallen 10% or more this year, and labor productivity has dropped a similar percentage. Oil production has fallen rapidly, leading to predictions that the Soviet Union could become an oil importer before the end of the decade.

Clouding any view of Central and Eastern Europe is the seemingly humdrum field of statistics: gathering them and then interpreting their reliability when gathered.

The Organization for Economic Cooperation & Development (OECD), for example, recently acknowledged that in Eastern Europe, government statistical offices have traditionally played a very different role from that of their counterparts in OECD countries. The transition from central planning to market economy doesn't merely mean that different kinds of statistics are required, but that working practices must be rethought, as well.

Formerly, for example, statistical offices collected and published few data in monetary terms, although detailed quantitative data on production of a vast range of products were collected. Each enterprise had its own production target, so offices were required to keep track of each enterprise. And statisticians were often under pressure to "improve" data to show that planned targets were being achieved, and they were expected to perform a propaganda function.

OECD advisers now recommend that countries begin collecting the national statistics that make up gross domestic or national product, for example, such as labor-force statistics and indexes of conpoint out that chemical prices are currently below the levels of a year ago in the U.S. and Germany, and have declined in real terms in the other major economies of the U.K., Italy, Canada, Japan, and France. Moreover, competition from outside Europe has become tougher because the U.S. is actively looking for overseas markets. The weakness of the dollar and of the yen in the first part of the year enabled surplus product from the U.S. and Asia Pacific to compete in European markets while making these markets less profitable to Europeans.

Wertheim Schroder's Church notes that although plastics do not represent the whole petrochemical industry, the trend in polymer prices is typical of what is happening to a major segment of the industry. For example, the price of low-density polyethylene was 2 German marks per kg last January and it now is 1.15 marks; polyvinyl chloride was 1.60 marks per kg in January and is now 1.05 marks.

The result is not surprising. Losses are beginning to appear on chemicals' profit-and-loss accounts. BP Chemicals was the first European firm to publicly declare a third-quarter loss and, judging from both industry statistics and conversations with management, the number of firms with losses will mount in the fourth quarter, Church says.

Bryan K. Sanderson, chief executive officer of BP Chemicals, is not optimistic about this year and next. "We think recovery might be longer and slower than predicted," he says.

Sanderson is not alone in that assessment. For example, Andrew Butler, president of Dow Europe, points out, "During the past 12 months, our industry has unquestionably entered a more painful phase of the business cycle, with current margins in many sectors barely covering interest costs, let alone generating any return on equity capital.

"Right now, we are caught between price erosion in our plastics on the one hand and steadily increasing hydrocarbon costs on the other. While we deal quite well with dramatic changes in hydrocarbon cost, it would appear we have much greater difficulty dealing with the current situation of overcapacity and creeping increases in feedstock costs."

Dow Europe's contribution to the 1991 corporate profit plan will more than be met, but will still be about half its 1990 contribution, the company says. A combination of several factors, including a 10% price drop and a 4% decline in sales volume since autumn last year, have depressed profit margins. In fact, the company reports that profit margins today are 50% lower than they were in 1989.

Moving from petrochemicals to downstream businesses, however, the gloom begins to lighten. Germany's Hoechst, for example, provides some indication of this. The general economic conditions were too strong not to mar the company's performance, of course. According to Hoechst chairman Wolfgang Hilger, following a generally disappointing first half-year, business activity in the chemical industry continued to lack momentum in the third quarter. Demand was still restrained, the mood subdued.

The strongest impulses continued to emanate from the German and Asian markets. Here, too, however, Hilgar says, "we noticed signs of a slackening in demand in the course of the third quarter. In our most im-

sumer and producer prices, and business tendency surveys. Countries are asked to publish regular reports on current economic statistics at preannounced dates, no matter whether politically well timed or not.

The former East Germany has been solidly folded into the fabric of the German nation, although there is still friction between cultures and economies. A few non-German investments have been made in the five eastern states, but most have been by German companies.

For example, Wolfgang Hilger, chairman of Hoechst, says his firm will invest roughly $440 million in eastern Germany in the next few years. "We intend to make our contribution toward the reconstruction of the eastern German states."

For other countries in Central and Eastern Europe, however, caution has been the watchword of the year—and promises to remain so in the coming year as well.

Most companies probably would agree with Finnish chemical producer Kemira, for example, on the longer term opportunities in Eastern Europe: environmental investments; renovation, rebuilding and modernization of existing industry; and feedstock supplies from Eastern Europe.

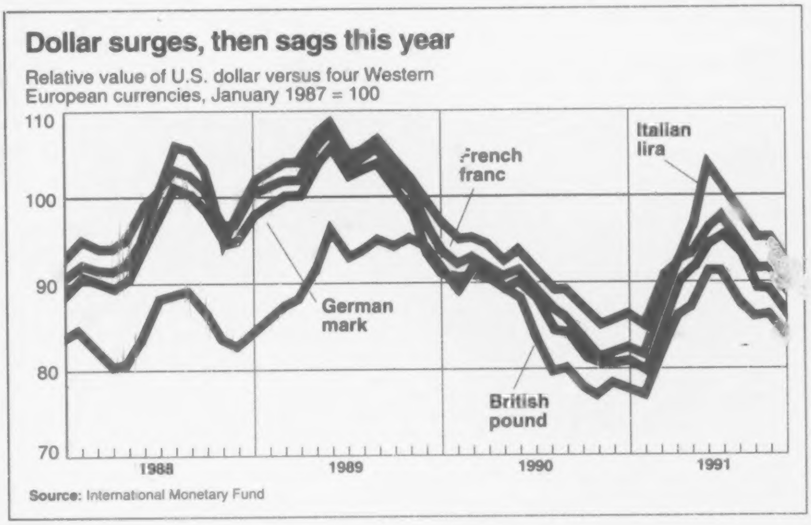
But there's also the political instability, the need to create marketing and distribution networks, and the difficulties in integrating western and eastern interests.

As officials at Shell put it, "The effect on demand from these countries will undoubtedly be positive in the longer term. In the short term, demand will be restricted by shortages of foreign exchange, but some will be met by imported products, though this will not remain the case as local modern plants are built."

A cautious approach in the short term will be the order of the day. For instance, a Unilever executive says: "Capital investment opportunities exist in all countries of the region, but our policy is to be cautious in making commitments until the direction of future political and economic development is clearer."

One answer, companies agree, is sales and marketing subsidiaries, and joint ventures, which western firms are increasingly relying on to build bridges between Western and Eastern Europe.

For example, Akzo, the Dutch chemicals producer, for a number of years has had sales organizations in Eastern Europe. But last year, it began what has become involvement with joint ventures, with a coatings venture in Hungary. Since then, it has set up another joint venture, for paper chemicals, also in Hungary. It has reached agreement in eastern Germany for cooperation with the rayon factory in Elsterberg. And in several countries of Central and Eastern Europe, the company is in contact with other prospective partners—prospective contacts that were not possible until recently.



Dollar surges, then sags this year

Relative value of U.S. dollar versus four Western European currencies, January 1987 = 100

Source: International Monetary Fund

portant market, Western Europe, business activity stagnated."

However, he adds, it's mainly the products at near-consumer level, especially pharmaceuticals, that have developed favorably in Germany. Plastics and fibers, on the other hand, are subject worldwide to heavy price pressure that is continuing unabated. And although the firm's pretax profit fell by 22%, its pharmaceuticals operations showed "an appreciable rise in profit."

That's not to say specialty producers haven't been buffeted in 1991. For example, at Unilever, whose specialty chemicals division makes up about 8% of corporate sales and 11% of operating profits, a spokesman says 1991 has been an exceptionally tough business year for chemical producers, with recession hitting particularly hard in markets in the English-speaking world. Durable goods markets such as automotive, electronics, and construction have been hardest hit, with other markets such as food and household products being less affected. And continental European markets have been less hard hit as a result of demand for consumer goods in a unified Germany and Eastern Europe.

Most major chemical companies, including those in Europe, are continuing to record weak financial results in 1991, and prospects for significant improvement in early 1992 are not strong.

"Specialty producers including ourselves are generally faring less badly with results equal to, or in some cases slightly ahead of, last year. As far as 1992 is concerned, our operating plans are based on a general continuation of weak demand for the first half with perhaps some improvement toward the end of the year," Unilever says.

Agreeing with this outlook, Sir Denys Henderson, chairman of ICI, says although economic conditions may not be deteriorating further, there is, as yet, little sign of any significant improvement in trading conditions "in most of our major markets."

The company's group profits before tax were up 22% for the third quarter. Pharmaceuticals had a record quarter, with continuing strong growth in newer products. In industrial chemicals, however, profit in chemicals and polymers was depressed by lower demand and pressure on prices, despite savings in fixed costs.

Finnish producer Kemira continued restructuring its fertilizer and paint operations during the year to enable the company to focus on its core businesses. Part of the restructuring involved divestment of noncore businesses and unsuitable parts of companies it had recently acquired. From its vantage point, European Community merger policy is not an obstacle for restructuring, although national policies and interests may affect restructuring. Kemira and other companies in countries in the European Free Trade Area (EFTA) are particularly alert to happenings in the European Community.

That has been especially true this year, which has become in essence the year of the European economic area, a free trade area made up of the 12 nations of the EC and the seven countries of EFTA.

In late October, the EC and EFTA agreed to create a new European economic market area of 380 million consumers stretching from the Arctic to the Mediterranean. Once formed in 1993, it will account for more than 40% of world trade. In 1990, the 19 countries accounted for 47% of total world exports and 46% of imports. Last year, 68% of the total trade of the 19 countries was done with other members of what will be the new European economic area, an important market that has been increasing over the past decade. For example, 58% of total EFTA exports in 1990 went to countries in the EC, compared with 53% in 1980.

By comparison, the U.S. conducted just 33% of its total trade with Canada and Mexico, partners in the new North American free trade area, in 1990; and other Asian countries accounted for just 30% of Japan's total trade, one reason for Japan's lack of enthusiasm for an Asian free trade area.

Prior to the agreement on the European economic area, EFTA countries—fearful they would be shut out of EC markets if they did not produce there—dramatically changed their patterns of foreign investment.

According to figures from the Organization for Economic Cooperation & Development, between 1982 and 1985, the EC was the destination for only 28% of foreign direct investment from EFTA countries. Between 1986 and 1988, however, this investment rose to nearly 60%. In the same period, the share claimed by North

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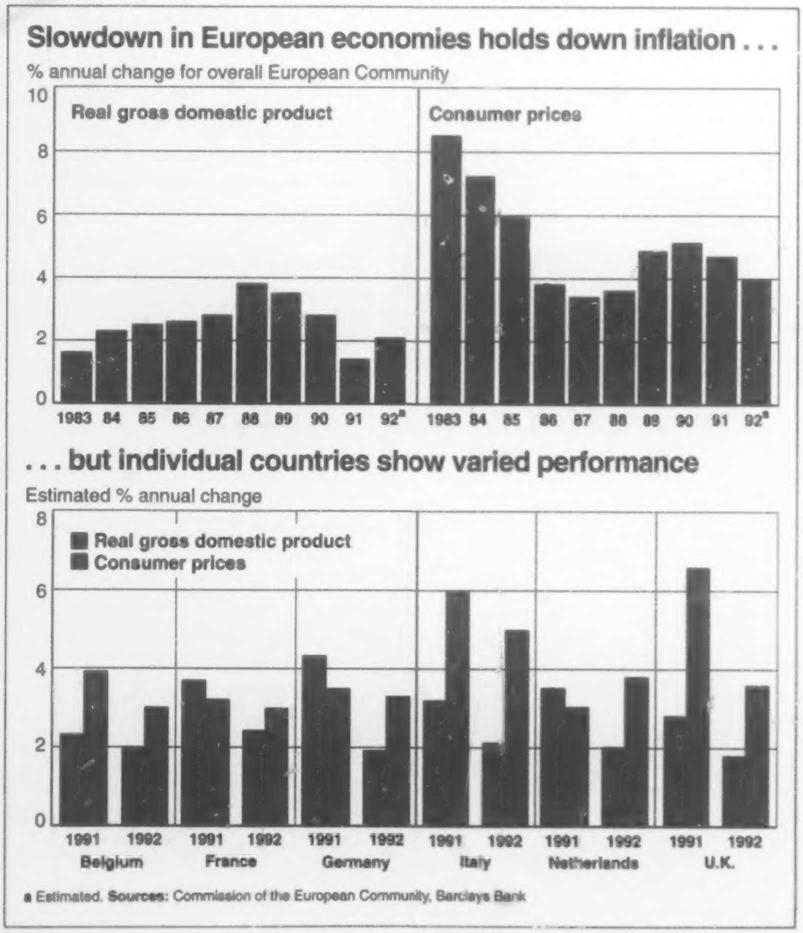
America fell from 48% to 13%. Chemicals were among the major industries buying into the EC, reflecting early concerns about free access to the EC markets.

Some of the investment has been in the petrochemical industry— buying in and building from scratch. That has helped contribute to the overcapacity that has begun to plague the industry.

"We are seeing a repetition of the early 1980s, although not quite so bad," says Peter Vogtländer, chemicals coordinator at Shell International Chemical Co. "For a mature industry, there are too many players, including some new players. The industry will have to sort itself out. We expect that a number of companies that had been holding on in 1987 to 1989—because they were making money, not because they were in core businesses—will now swap portfolios, go out of these businesses, and so on."

At a recent conference in London, J. D. (Doug) Campbell, deputy chief executive of BP Chemicals, said, "Due to the long stock chains between upstream ethylene and final consumption, we have a time lag in our system. This means that we may not see the effect of an economic recovery, which some say is beginning now, for at least a year—perhaps not until 1993. It would be grossly optimistic to expect a major recovery in demand in the near future to lead us out of our present troubles.

"We went into the 1980s with a stock of inefficient plants, but no one made any closure decisions until the blood was running in rivers of red on [profit and loss statements]. I think we would all rather not bleed this profusely again. Hard decisions need to be made again, harder than last time. It seems possible that some ethylene crackers, some integrated operations, even some entire petrochemicals sites are now in the red."



Slowdown in European economies holds down inflation . . .

% annual change for overall European Community

. . . but individual countries show varied performance

Estimated % annual change

a Estimated. **Sources:** Commission of the European Community, Barclays Bank

He makes two suggestions for solving the problem: one, to reduce production to levels "that more clearly match market demand," a course of action he believes may have begun; and two, to close temporarily or mothball surplus capacity.

Whatever course of action is taken something clearly must be done to relieve the industry—an industry about which David S. Glass, a director with London-based consultants Chem Systems Ltd., comments: "This is not a cyclical industry. It's an industry that doesn't usually make any money, and then every once in a while it has a hiccup."

It won't turn up unless the industry does some dramatic things, he argues, particularly since over the next 12 months, more than 1 million metric tons of new ethylene capacity is being brought on stream in Europe. This can only exacerbate conditions that have meant that, in terms of return on capital employed, profit margins in the fourth quarter are the worst in more than 15 years—and that is for the most efficient crackers.

"Everybody is losing big money" in the petrochemicals industry in the third and fourth quarters of 1991, agrees Wertheim Schroder's Church. "There is no gentle way out. If the price of oil goes up $10 tomorrow, a buyer then would have a reason to buy to hedge. However, over the past two or three months, perception and reality have come together," and the buyer holds the trump cards. "It is all well and good for producers to strut around and say they will raise prices, but they are cut down each time. The only answer can be to get capacity closed, costs down, and hunker down to wait out the recession."

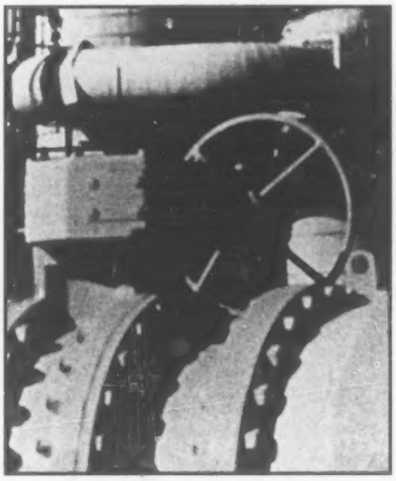
Church predicts "an appalling first half in 1992, perhaps with some relief by the end of the year." The higher value-added products will be the quickest to benefit, because they are nearer to the consumer. However, it probably will be near the end of 1992 before the benefits of any pickup in demand ripple back to bulk producers.

Without much similar action, or actual capacity cutting, however, the outlook for next year's petrochemicals industry looks much the same as this past year. □

Chemical outlook turning bleak

Sluggish demand coupled with rising costs means stagnant sales, lower profits for Japanese companies

Earl V. Anderson
C&EN Northeast News Bureau



Economic growth in Japan is slowing down. The country's Economic Planning Agency says that, although the Japanese economy is basically sound, it is now Japan's turn to prepare for "an economic soft landing."

But for many of Japan's troubled chemical companies, the landing may be anything but soft. For several years, these companies have prospered as costs remained low and demand increased.

Now, the situation is reversed. Costs are rising and demand is dropping. As a result, Japanese chemical company profits are going to take a hit—in some cases a big hit.

One harbinger of things to come is the financial results of Japanese chemical giant Mitsubishi Kasei. For the first half of fiscal 1991 (April 1991 through September 1991), the company's sales dropped 3.4%. But its unconsolidated pretax profits plunged a whopping 54%.

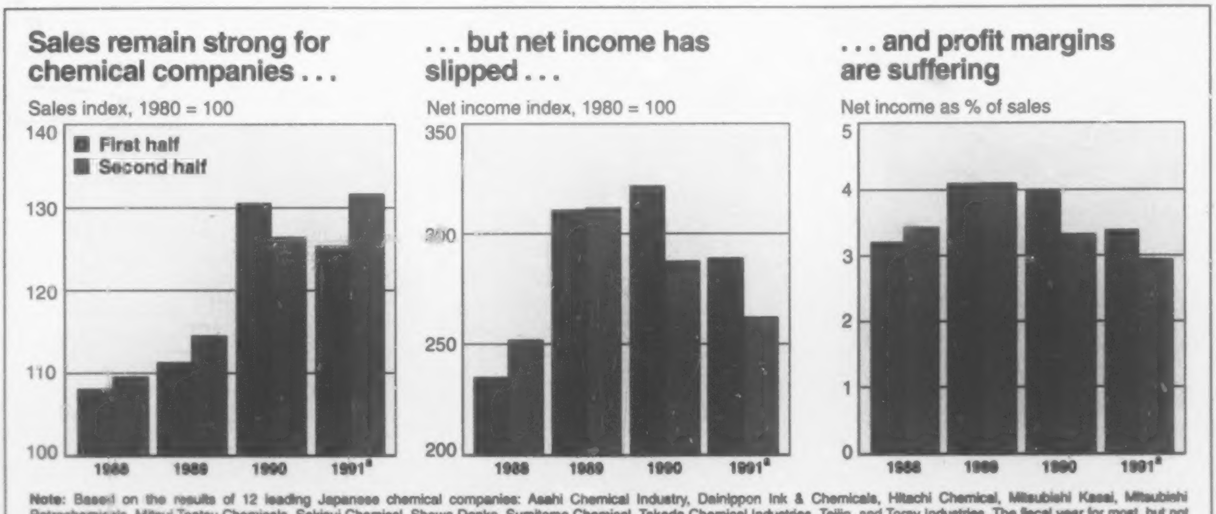
As a result of this poor performace, Mitsubishi Kasei has lowered its profit projections 42% for the full fiscal year. Sales projections have been lowered a more modest 5%.

Mitsubishi Kasei will not be alone. C&EN indexes based on the expected results of 12 major Japanese chemical companies indicate that, although sales will remain virtually flat in fiscal 1991, net income will be down an average 9 to 10%. Among the other chemical companies that anticipate lower profits this year: Mitsubishi Petrochemical, Mitsui Petrochemical Industries, Mitsui Toatsu Chemicals, Showa Denko, and Sumitomo Chemical.

This is not what executives of Japanese chemical companies expected at the beginning of the year. Then, the consensus was that sales would increase modestly and profits would, at worst, remain flat.

That's not the consensus now. A recent survey by the Japan Petrochemical Industry Association finds that recent shipments of some key petrochemicals have been declining. It is certainly true of the major plastics, such as both low- and high-density polyethylene, polyvinyl chloride, polystyrene, and polypropylene.

Another survey—this one by the Japan Chemical Industry Association (JCIA)—mirrors the pessimism. It portrays Japan's chemical business as "increasingly stagnant" and says the


Sales remain strong for chemical companies . . .
. . . but net income has slipped . . .
. . . and profit margins are suffering

Note: Based on the results of 12 leading Japanese chemical companies: Asahi Chemical Industry, Dainippon Ink & Chemicals, Hitachi Chemical, Mitsubishi Kasei, Mitsubishi Petrochemicals, Mitsui Toatsu Chemicals, Sekisui Chemical, Showa Denko, Sumitomo Chemical, Takeda Chemical Industries, Teijin, and Toray Industries. The fiscal year for most, but not all, of these Japanese companies ends March 31 of the following year. a Estimated for second half. **Source:** Toyo Keizai business slump will spread from petrochemicals to organics, end-products, and other sectors of the chemical industry.

Many replies to the JCIA questionnaire say business conditions will continue to deteriorate and the "recessionary mood" will remain until the middle of next year. The chief culprits are sluggish sales of passenger cars and household appliances and the low number of new housing starts.

Adding to their profit problems is the relatively high price of naphtha, the major petrochemical raw material in Japan. Naphtha prices shot up after Iraq invaded Kuwait. They have since gone back down, but they still remain higher than pre-Persian Gulf War levels.

Ironically, because naphtha prices have retreated following the Persian Gulf War, customers are pressuring chemical producers to lower their prices. Many are gradually, if reluctantly, responding, says Masahiko Furukawa, president of Mitsubishi Petrochemical.

This disappointing business outlook only started to surface late in the year. Through August, there were relatively few major chemicals whose production was much lower than it was last year. Among the most notable are benzene, acrylonitrile, cyclohexane, methanol, and several inorganics.

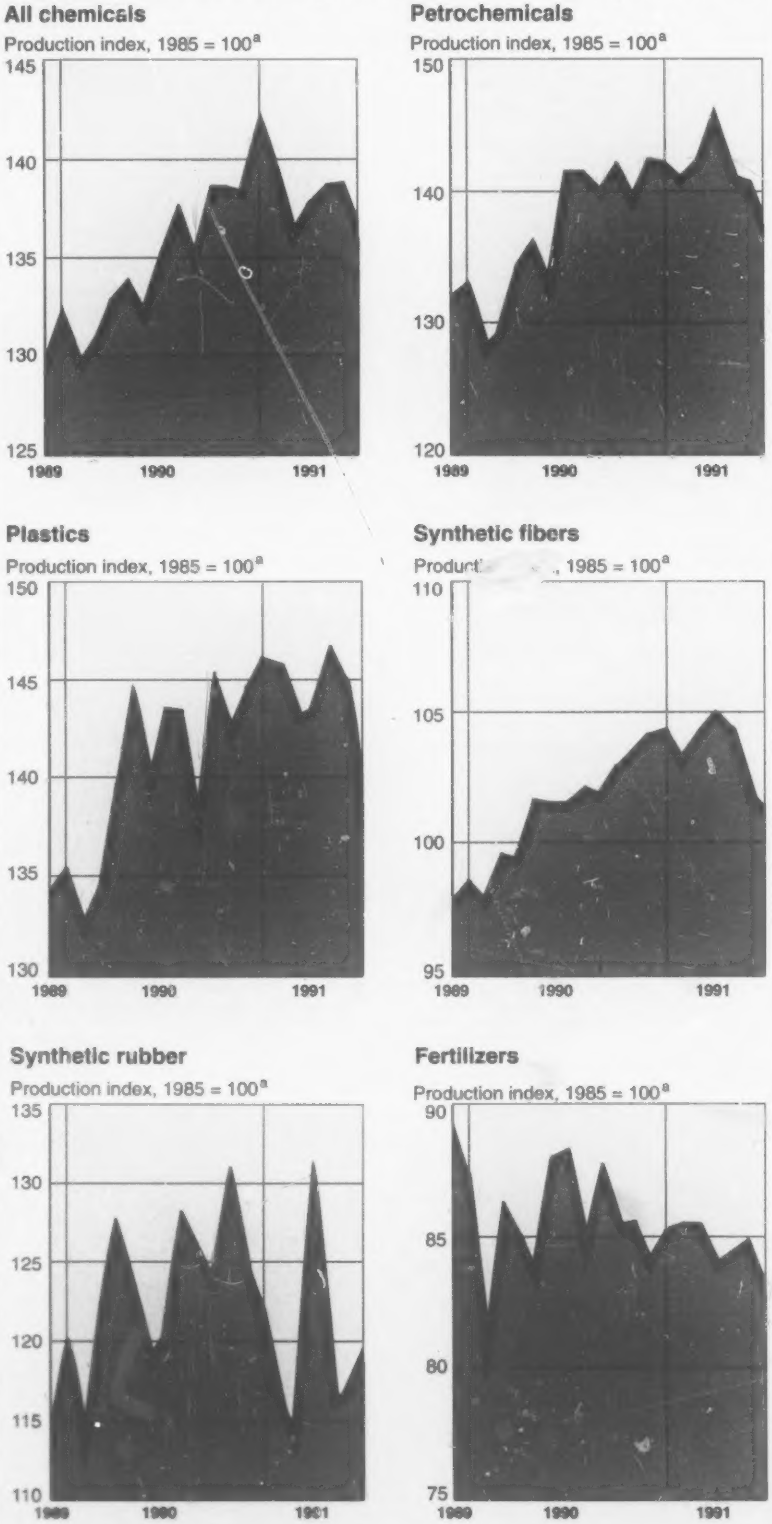
Until August, many of the major petrochemicals held up very well. Polyethylene output was up almost 20%. And production of polystyrene, polypropylene, and polyvinyl chloride had increased between 2 and 6%. Ethylene production responded with a 7% gain.

Since August, it has been a different story. Petrochemical demand usually increases after September. But petrochemical producers report that demand has remained sluggish. According to very preliminary figures, 10 of the 17 major petrochemicals suffered an average 10% drop in production in October.

As a result, producers are trying to reduce inventories and lower costs. And they are fighting hard to keep prices up in the face of declining demand.

But production cutbacks seem inevitable. And they may last for some

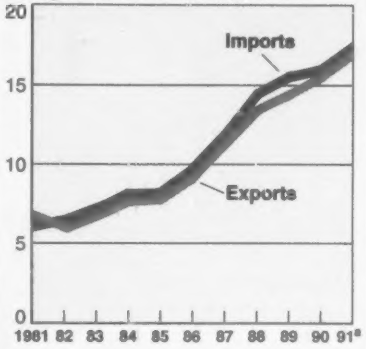
Signs of weakness emerge in Japan's chemical production



a Seasonally adjusted. Source: Ministry of International Trade & Industry

Japanese chemical exports, imports show strong growth

Foreign trade in chemicals, $ billions



a C&EN estimates.
Source: Ministry of International Trade & Industry

time. In the face of these new realities, Japanese chemical companies are trying to keep plant operating rates as high as possible by pushing exports, particularly to China and to Southeast Asia. They apparently are succeeding. This year, Japan's chemical exports likely will increase almost 10% to $17.4 billion.

Meanwhile, chemical imports also are rising. They likely will increase about 11% this year to $17.8 billion. Japan has had a chemical balance of trade deficit for the past nine years, but it all but disappeared last year. This year, however, deficit will jump back up to an estimated $450 milion.

The Japanese chemical export drive, however, could be sailing into rough water. South Korean petrochemical producers have put a lot of new capacity on stream recently. And they are eyeing the same export markets that Japanese chemical companies are.

Korean petrochemicals could even become a competitor for Japanese companies in their home market. And, to make matters worse, as Korean naphtha demand increases, naphtha prices probably will go up, tightening the cost-price squeeze on Japanese petrochemical producers even more.

Capital spending and personal consumption have been the twin engines that have fueled Japan's economic expansion. Both are weak now. In fact, capital spending in Japan is projected to decline in the next fiscal year starting April 1992. It will be the first annual decline in six years.

Most Japanese companies cite economic uncertainty as the primary reason for their spending cutbacks. And this uncertainty will have an impact on the Japanese chemical industry.

Typical of this impact is Asahi Chemical's decision to scrap plans to expand its Chiba polystyrene plant. Asahi has 330,000 metric tons of polystyrene capacity and had planned a 50,000-metric-ton increase by next October. But, faced with declining polystyrene demand and increased worldwide capacity, Asahi opted out of the expansion.

Meanwhile, several ethylene producers have started cutting back on production. Tosoh Corp. has decided to delay for one year the startup of its planned, 400,000-metric-ton ethylene plant until the spring of 1995.

There no doubt will be more production cutbacks and more scrapped expansion plans before Japan's economic "soft landing" is over. ☐

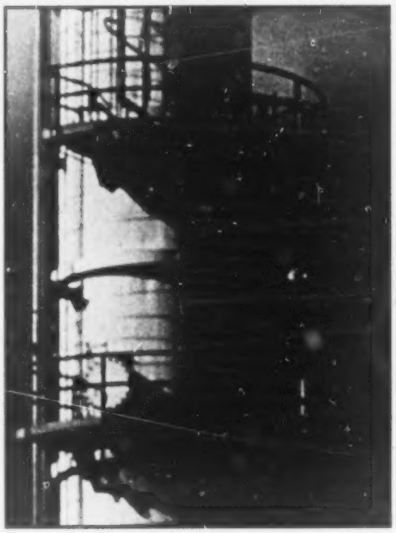
Output of ethylene and derivatives remains healthy

Thousands of metric tons unless otherwise indicated	1990	Seven months 1991	Seven months 1990	% change
INORGANIC CHEMICALS				
Ammonia	1831	960	1047	−8%
Ammonium chloride	246	147	147	0
Ammonium sulfate	1803	1052	1059	−1
Calcium carbide	294	190	183	4
Calcium superphosphate	472	256	289	−11
Carbon black	783	464	394	18
Chlorine, liquid	1042	615	609	1
Hydrochloric acid	637	291	350	−17
Nitrogen[a]	8299	5038	4733	6
Oxygen[a]	8787	5255	4998	5
Sodium carbonate	1135	658	664	−1
Sodium hydroxide	3917	1971	2257	−13
Sodium silicate	788	308	441	−30
Sulfuric acid	6887	4155	4000	4
Titanium dioxide	280	161	164	−2
ORGANIC CHEMICALS				
Acetaldehyde	384	222	212	5
Acetic acid	462	247	251	−2
Acetone	334	206	199	4
Acrylonitrile	593	305	339	−10
Benzene[b]	2768	1492	1708	−13
Butadiene	827	498	475	5
Butanol	300	184	164	12
Caprolactam	509	314	300	5
Cyclohexane	629	332	382	−13%
Dioctyl phthalate	295	178	143	25
Ethylene	5810	3535	3307	7
Ethylene dichloride	2660	1539	1529	1
Ethylene glycol	501	354	255	39
Ethylene oxide	674	371	391	−5
Methanol	84	53	62	−15
Octanol	283	165	149	11
Phenol	403	268	244	10
Phthalic anhydride[b]	161	89	94	−5
Propylene	4215	2551	2402	6
Propylene glycol	298	171	170	1
Styrene	2215	1334	1179	13
Terephthalic acid	1338	858	738	16
Toluene	1078	639	611	5
Toluene diisocyanate	116	74	56	32
Urea	776	438	362	21
Xylene	2652	1652	1511	9
PLASTICS				
Phenolic resins	385	227	222	2
Polyethylene	2888	1726	1444	20
Polypropylene	1942	1137	1096	4
Polystyrene	2097	1240	1173	6
Polyvinyl chloride	2049	1190	1162	2
SYNTHETIC RUBBER	1426	809	824	−2

a Millions of cubic meters. b Petroleum-based product only. **Source:** Ministry of International Trade & Industry

CANADA

Chemical firms expect another tough year



Weak domestic demand and lower prices spell lower sales and earnings for many producers

Earl V. Anderson
C&EN Northeast News Bureau

Technically, Canada's recession ended in the first quarter. But you would be hard-pressed to get many Canadian chemical executives to agree. And you certainly never would know it from the sales and earnings statements of many Canadian chemical companies.

For most of them, lower sales and earnings were the order of the day during the first half of the year. It was not until the third quarter that they started to see some improvement in their bottom lines.

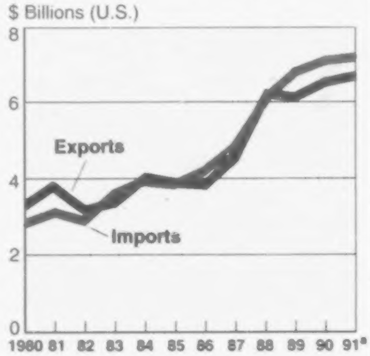
Even then, the improvement was not enough to overcome the losses Canadian chemical companies chalked up in the first half. And even though some leaders in the Canadian chemical industry think that sales and earnings will continue to improve in the fourth quarter, they concede that the improvement will be nothing to brag about. Many Canadian chemical companies still will be left with red ink for the entire year.

It's not difficult to find the reasons. The domestic economy has continued to be weak in Canada, even though the recession may have ended early in the year. That has meant weak domestic demand for chemicals. Indeed, chemical shipments have been running about 3% lower in 1991 than last year. Even August's chemical shipments (the latest month for which data are available) were still 3.4% below year-end levels of 1990.

Along with weak shipments comes weak prices. Canadian chemical producers have contended with weak prices all year. And the inevitable result of lower shipments and lower prices is lower sales and earnings. Only recently have prices begun to recover for some products that are the mainstays of the Canadian chemical industry.

Even the Canadian dollar has had a negative impact on the country's chemical producers. The Bank of Canada has kept the Canadian dollar very strong to combat inflation in the country. But a strong currency tends to penalize exports and stimulate imports.

Little change in Canada's chemical trade this year



a C&EN estimates. **Source:** Statistics Canada

That's not a welcome situation for the Canadian chemical industry. It, and especially the petrochemical sector with its large, world-scale plants, is heavily export-oriented. DuPont Canada, for instance, exports more than 55% of its production.

Partly as a result of the strong Canadian dollar, Canadian chemical exports this year probably will increase only 0.2% to about $6.7 billion in U.S. dollars (1.7% in Canadian dollars). Another reason for the listless export performance is the weak economy in the U.S. About 70% of Canada's chemical exports end up in the U.S.

Meanwhile, Canadian chemical imports will decline 0.4% this year to $7.2 billion in U.S. dollars (they will actually increase 1.2% in Canadian dollars). True, the strong Canadian dollar would be expected to result in a stronger growth in chemical imports. But its impact has been partially offset by the country's weak economy.

Faced with this inhospitable market climate, output of most Canadian chemicals will decline this year, with very few exceptions. Two of the most notable exceptions, however, will be high-density polyethylene (HDPE) and sodium chlorate.

HDPE is one of the very few products that has been blessed with a strong export market. As a result, output probably will be up this year about 20% to 440,000 metric tons.

Other major petrochemicals won't be that fortunate. Output of low-density polyethylene (LDPE) will be down almost 8%, and polystyrene production will shrink a hefty 21%.

Nitrogen fertilizers continue to be hard hit. Ammonium nitrate output probably will end the year about 8% lower than last year; production of ammonia and urea will be down 2.1% and 1.2%, respectively. Not surprisingly, output of sulfuric acid, a

Very few chemicals buck the production downtrend

Thousands of metric tons	Production 1991[a]	1990	1989	1988	1987	% change 1990–91
Ammonia	3550	3602	4054	4012	3512	−2%
Ammonium nitrate	950	1031	1056	990	844	−8
Benzene	640	765	670	695	720	−16
Chlorine	1410	1542	1592	1664	1635	−9
Ethylene	2510	2425	2317	2346	2140	4
Hydrochloric acid, 100%	185	187	180	180	164	−1
Nitric acid, 100%	910	965	1027	919	900	−6
Polyethylene, high density	440	364	303	311	269	21
Polyethylene, low density	1075	1167	1039	1105	1021	−8
Polystyrene	170	215	196	216	197	−21
Propylene	740	766	719	672	628	−3
Sodium chlorate	715	658	593	503	432	9
Sodium hydroxide	1500	1651	1679	1720	1770	−9
Sulfuric acid	2895	3311	3560	3805	3437	−13
Toluene	380	427	397	417	396	−11
Urea	2460	2490	2402	2372	4142	−1
Xylene	425	514	432	399	345	−17

a C&EN estimates. **Source:** Statistics Canada

reliable barometer of both the industrial and agricultural chemical markets, will be 13% lower than last year.

All of these factors—weak domestic demand, lower production, weak prices, a strong Canadian dollar, and lackluster exports—are apparent in the performance of many Canadian chemical companies. Celanese Canada is a good example.

Typical of many Canadian chemical companies, Celanese Canada garnered higher sales and earnings in the third quarter but, through the first nine months, net income still was lower than it was last year. One reason, according to the company: "The weak domestic market and heightened competition from imports due to the high value of the Canadian dollar" hurt its polyester business.

DuPont Canada also scored slightly higher sales and much higher earnings in the third quarter, yet managed to stay in the red for the first nine months. Some of those lower earnings were caused by depressed world prices for polyethylene and lower domestic volumes.

Nova Corp. of Alberta, which depends heavily on commodity petrochemicals, has been particularly hard hit this year. Through the first nine months, chemical sales and earnings are down 32% and 94%, respectively. Nova blames an industrywide squeeze on prices for much of its chemical profit problems.

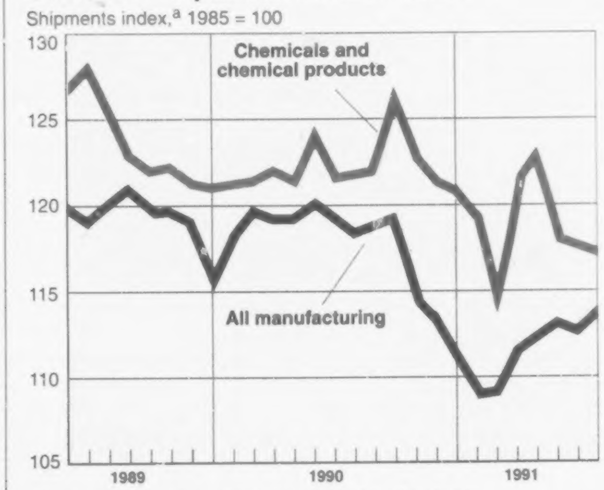
Nova expects prices to stabilize as the North American economy recovers from recession. "If" it recovers is probably a safer way of saying it. Even if it does, the economy will not become an instant worldbeater.

D. John Ogren, president and chief executive officer of DuPont Canada, notes that the "level of economic activity" is still extremely weak. "We expect this recovery will continue to be mild," he says. And future export growth will depend upon the strength of the U.S. recovery.

Alban W. Schuele, president of Celanese Canada, says the speed at which the economy is expected to recover from recession "is uncertain." When this quarter's results are in, he expects them to be better. But he also expects that the strong Canadian dollar will continue to put pressure on the company's export earnings and lead to stiffer competition in the domestic market from imports.

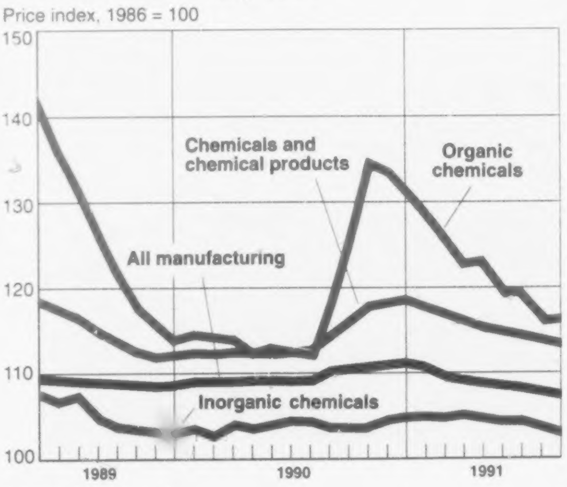
Apparently, next year will be a better one for Canadian chemical companies. But not much better. ☐

Chemical shipments remain weak . . .



a Seasonally adjusted. **Source:** Index based on Statistics Canada data

. . . as do chemical prices



Source: Statistics Canada

Chemical companies hold the
line on capital spending
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DECEMBER 23, 1991
CHEMICAL & ENGINEERING
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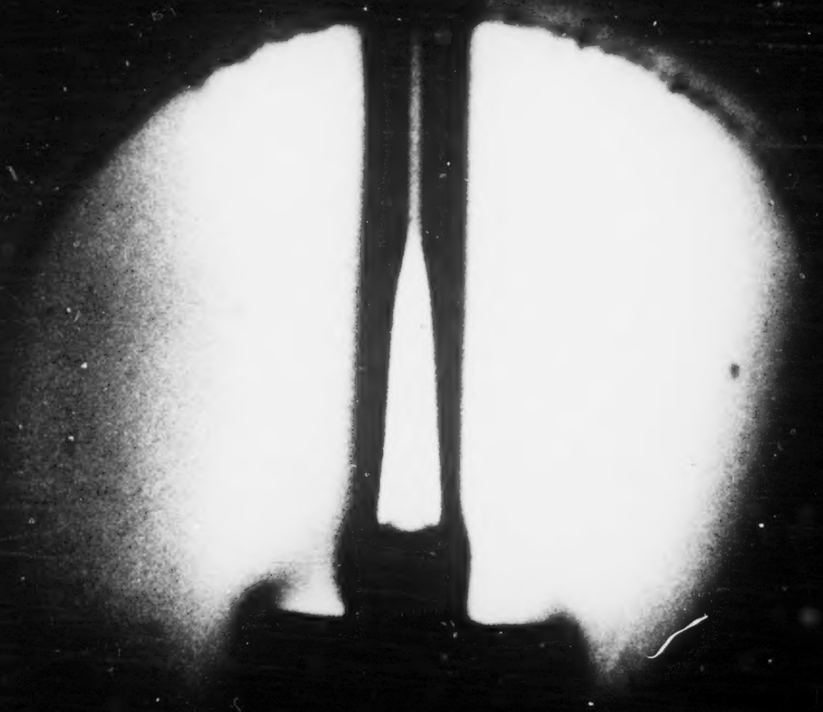

SUPERCRITICAL WATER

A medium for novel chemical reactions
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CHEMICAL & ENGINEERING
NEWS

Volume 69, Number 51
CENEAR 69 (51) 1–52
ISSN 0009-2347

DECEMBER 23, 1991

News of the Week

- **Union Carbide plans to split into two companies next year, a chemical and plastics unit bearing the Carbide name, and an as-yet-unnamed industrial gases firm.** Page 4
- **Worst job market in 20 years is projected for next June's college graduates, though B.S. chemists may buck the hiring trend.** Page 5
- **Annual Christmas show of "chemical magic" is performed by University of Wisconsin's Bassam Shakhashiri.** Page 5
- **U.S. approach to controlling low-level ozone, a major smog component, has essentially failed and major changes are needed, finds a recent study.** Page 6
- **Explosion in a benzoic acid tank at a chemical complex of Dutch chemical firm DSM in Rotterdam kills six people.** Page 6
- **Du Pont is taking a huge write-off for damage to greenhouse nursery plants caused by its fungicide Benlate.** Page 6

Business

Global capital spending by major U.S. chemical firms will rise slightly in 1992, as the economy continues to languish. **Page 9**

Government

EPA will review policy on risk assessments at Superfund hazardous-waste sites following legal challenge by the Chemical Manufacturers Association and other industry groups. **Page 15**

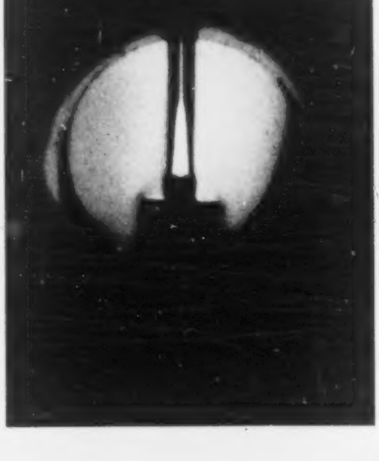
Science/Technology

Chem Show exhibits reflect influence of environmental concerns and new construction materials on process equipment design. **Page 17**

Recent CHEMRAWN conference tackles effects human activities are having on the atmosphere as well as effects atmospheric changes are having on humans and Earth. **Page 21**

Public Policy

Academic research and its problems and future were explored in a meeting sponsored by NAS's roundtable group. **Page 23**



Cover: Flame burns in supercritical mixture of water and methane in work at the University of Karlsruhe, Germany

Special Report

Supercritical water is emerging as a medium that could provide the optimum conditions for a variety of chemical reactions, among them the destruction of hazardous waste. Page 26

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
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Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

A true hero

I want to commend you for your article "Milton Harris: a Distinguished, Joyous Life in Chemistry" (C&EN, Nov. 4, page 42). Your title was just right in describing the wonderful, productive life that Harris lived.

I met him in 1962 when I was a young program director in chemistry at the National Science Foundation. I was very active in ACS and became friends with him at that time. Harris gave me a great deal of useful help both professionally and personally. He was a wise, kind, and thoughtful man, always willing to take time from his busy schedule to be helpful to others. I know that what he did for me he also did for hundreds of others throughout his long and distinguished career.

I wish ACS would produce a booklet on his life and career, to be used to inspire high school students. You could show how one person can do so much for society through chemistry. Harris is a hero of true character as contrasted to many of the sports heroes of today who all too often betray their youthful followers.

Robert H. Linnell
President, Harmony Institute Inc.
Tollhouse, Calif.
Professor Emeritus, University of Southern California

Faraday exhibits in London

On a recent trip to London I came across a few items relating to Michael Faraday that I thought C&EN readers might find interesting, especially after reading your cover story (C&EN, Sept. 23, page 17).

- The Science Museum has a special exhibit, "Michael Faraday and the Modern World," which covers Faraday's life and work, modern applications, and many hands-on experiments. The really special event of the exhibit is a young actor (Robert Hulse) who does a first-person interpretation of a Faraday lecture. This fellow has the science and history together and does a lively presentation.
- The Royal Institution has restored Faraday's laboratory in the basement of its building at 21 Albermarle St. It's open to the public on a regular basis on Tuesday and Thursday afternoons. On display are many of his original experimental pieces, including Faraday's ring (not a piece of jewelry), the great electromagnet, samples of optical glass and steel alloys prepared by Faraday, and many of his journals and letters.
- The Royal Institution also has for sale a good selection of publications on Faraday and his work, including a little 36-page booklet, "Advice to Lecturers," taken from the writings of Faraday and Lawrence Bragg. It's a piece that should be required reading for all of us who ever stand up before an audience.
- Michael Faraday has replaced Shakespeare on the back of the £20 note. I see that as a good sign for science and technology.

Bierce Riley
Morristown, N.J.

Raising gasoline taxes

Along with David Montgomery, I authored the Charles River Associates (CRA) report criticized by William J. Sapone (C&EN, Nov. 4, page 4). Although C&EN's description of our report findings (Sept. 23, page 12) is accurate and fair, I wish to clarify the points where Sapone misunderstands our report, its conclusions, and the motivations that underlay its creation.

CRA's report, "Policy Alternatives for Reducing Petroleum Use and Greenhouse Gas Emissions," was commissioned as an independent study by the Motor Vehicle Manufacturers Association (MVMA) to analyze a variety of policies that might be implemented to save petroleum, including increased corporate average fuel economy (CAFE) standards and gasoline taxes. We concluded, among other things, that raising gasoline taxes would be a cheaper way of saving petroleum than mandating increased fleet fuel economy standards.

Sapone's argument is based on an incorrect notion that driving patterns are not affected by gasoline prices. For example, he erroneously states that "people primarily use their cars for work and that type of driving cannot be curtailed." In fact, work trips account for less than 40% of all auto travel in the U.S. And because he does not take account of price sensitivity, he mistakenly believes that gasoline taxes and increased CAFE standards will have the same impacts on petroleum use. He argues that consumers will respond to

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Chemical Capital Spending Forecast To Rise Modestly in 1992

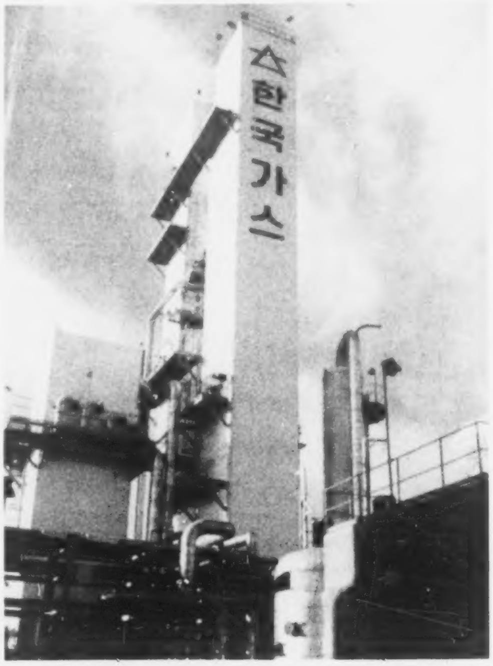
Caution is watchword for major U.S. chemical firms as recession continues, but spending on pollution control will continue unabated

Marc S. Reisch,
C&EN Northeast News Bureau

Spending for plant efficiency, incremental increases in capacity, and government-mandated pollution abatement will likely characterize capital expenditures in 1992. As a result, in the absence of significant grassroots construction, worldwide capital spending by major U.S. chemical producers will increase only modestly in the next 12 months, according to preliminary forecasts of plans by leading chemical producers.

For eight chemical producers responding out of the 12 that C&EN surveys annually, 1992 capital expenditures will increase a modest 4% from 1991 to a combined $7 billion. That forecast follows an 11% drop in 1991, also gleaned from this year's survey.

However, of the eight chemical producers, only one—PPG Industries—expects to increase such spending significantly. A PPG spokesman says virtually all of the 14% increase planned in 1992, some $40 million to $50 million, will be directed to environmental expenditures for the company's chemical business. Four other companies intend to spend less than in 1991 on capital projects or plan no increase at all. Two others will increase spending, but not by so large a percentage as PPG.



Air Products joint venture industrial gas plant in South Korea is currently being expanded

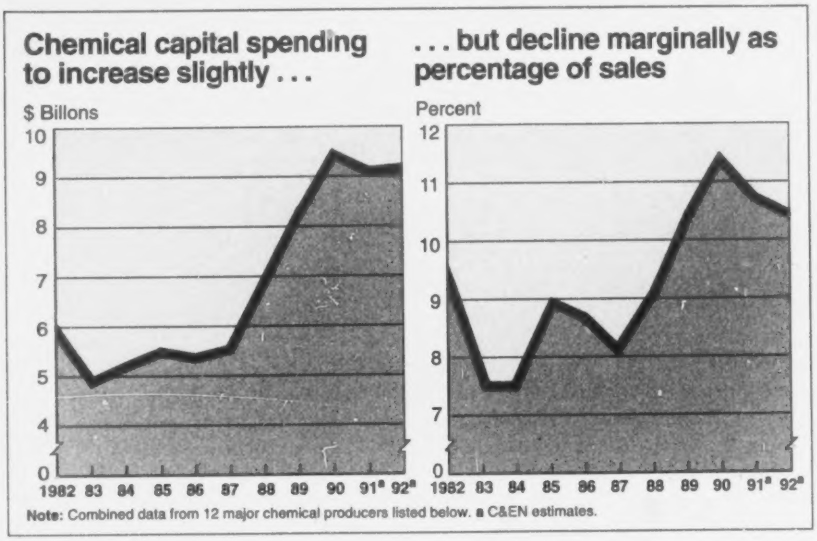
According to Du Pont chief economist Richard A. Stuckey, in contrast to consumer confidence, business confidence has not plunged. However, business executives are nonetheless hesitant about spending money for capital improvements in the current languishing economy. As a result, Stuckey says, industry's spending for capital projects will be directed mostly at efficiency improvements, expansions of existing capacity, and spending related to environmental considerations.

Pollution abatement spending is a constant in capital budgets and is not subject to the cyclical influences that affect decisions to add capacity or build new plants from the ground up, notes Stuckey. In addition, a large part of any one year's capital budget goes for the installation of equipment to produce products that are considered more "environmentally friendly" than the products they replace. Such would be the case for investments in water-thinned acrylic polymers for paint to replace solvent-thinned alkyd resins. Another might be investments in replacements for chlorofluorocarbons used as refrigerants and blowing agents.

Totaling up costs for new products intended to replace older, less "environmentally friendly" products would be difficult, but the costs would be significant. Stuckey says the addition of pollution abatement equipment in the expansion of existing product lines often doubles the cost of the expansion.

Saadat Sayal, vice president of international marketing for the Greater Houston Partnership, says chemical industry spending in the Houston area has slowed significantly since the 1987–89 period. Houston is a major center of the U.S. petrochemical industry, and the partnership promotes area commercial development. The most significant capital projects under way now in the Houston area are expansions for methyl *tert*-butyl ether, a gasoline additive that helps motor vehicles meet government-mandated exhaust limits, notes Sayal. Where companies are planning investments, they are doing so to come into compliance with environmental regulations. In a number of instances, he notes, chemical producers are planning individual investments of up to $100 million each to bring their complexes into compliance.

In the Commerce Department's 1988 survey of capital expenditures for pollution abate-



Note: Combined data from 12 major chemical producers listed below. a C&EN estimates.

ment, chemical industry spending to curb air and water pollution and solid waste was estimated to make up nearly 7% of total chemical capital spending of $19.3 billion. Although the government no longer publishes this survey, other sources indicate that the percentage is up significantly from what it was as little as three years ago.

The Chemical Manufacturers Association's (CMA) annual industry survey provides data showing that chemical industry costs for air, water, and solid-waste abatement totaled about $1.8 billion in 1990, or nearly 9% of 1990 industry capital expenditures. However, using a measure of gross industry spending that excludes spending of diversified chemical companies on nonchemical businesses, CMA indicates that 17% of industry capital expenditures of $11.5 billion in 1991 were for pollution controls. It says that that percentage will rise to 22% of industry spending of $12.6 billion in 1992. Most chemical companies surveyed by C&EN say pollution spending as a percentage of their total capital spending would grow.

But while spending on pollution abatement is on the increase, most expansion projects for the industry are on hold. The past year, after all, has been a trying one for the chemical industry. Since the middle of 1989, demand for chemicals has been declining. Though CMA predicts record U.S. chemical exports of $43.5 billion this year, exports do not ultimately substitute for the serious lag in domestic demand. As a result, capacity utilization rates have dropped. In its annual report on the industry's economic performance, CMA pegs average 1991 capacity use at 78.7%, down substantially from the 1990 rate of 81.4%. The industry operated at peak capacity as recently as August 1988, when capacity utilization reached 86.8%.

A significant reason for the low chemical industry capacity use is that major automotive and construction industry customers are themselves in a deep economic rut. With capacity use down and prices up hardly enough to account for inflation, the chemical industry cannot justify huge increases in capacity expansions. And even if it took a long-term perspective, and forgot Wall Street looking over its shoulder, the industry's nine-quarter earnings slide would make industry management leery of spending cash without good reason.

As a result of the continuing uncertain economy, companies are very late in planning next year's capital budgets. This is the fourth year in a

Capital spending of surveyed companies will increase 4% next year

	1992		1991		Worldwide					Change from previous year	
$ Millions	Total	U.S.	Total	U.S.	1991 planned[a]	1990	1989	1988	1987	1992	1991
Air Products[b]	$ 492	$ 364	$ 506	$ 338	na	$ 468	$ 414	$ 409	$ 323	−3%	8%
American Cyanamid[c]	385	285	385	285	$ 370	376	398	374	268	0	2
Dow Chemical	2000	1200	2000	1100	2000	2119	1756	1264	995	0	−6
Du Pont[d]	2970	2020	2735	1915	3170	3142	2563	2029	1674	9	−13
Ethyl[e]	165	115	175	105	185	166	119	151	139	−6	5
W. R. Grace	na	na	400	na	na	514	485	418	243	na	−22
Hercules	200	160	225	180	225	273	293	251	205	−11	−18
Monsanto	na	na	600	na	na	750	607	590	505	na	−20
Olin	na	na	195	na	na	187	142	147	115	na	4
PPG Industries	400	225	350	200	450	567	671	410	426	14	−38
Rohm & Haas	300	200	285	190	325	412	385	338	222	5	−31
Union Carbide	na	na	750	525	na	744	726	608	452	na	1
TOTAL	**$6912**	**$4569**	**$8606**	**$4838**	**$6725**	**$9718**	**$8559**	**$6989**	**$5567**		
ANNUAL CHANGE[f]	**4%**	**6%**	**−11%**	**−14%**		**14%**	**22%**	**26%**	**4%**		

a Earliest estimate. b Fiscal year ends Sept. 30. c 1990, 1991, and 1992 excluded Shulton Group, which has been sold. d Excludes Conoco. e 1989, 1990, 1991, and 1992 figures adjusted to reflect spin-off of Tredegar Industries in July 1989. f Cumulative changes for companies reporting. na = not available.

row when fewer than 11 companies have responded to C&EN's December survey. Although 11 firms responded in 1987, only nine responded in 1988 and eight in 1989, 1990, and 1991.

Companies responding this year were Air Products & Chemicals, American Cyanamid, Dow Chemical, Du Pont, Ethyl, Hercules, PPG Industries, and Rohm & Haas. Missing this year are W. R. Grace, Monsanto, Olin, and Union Carbide.

Though the survey shows an average increase of 4% in capital expenditures for reporting companies, most individual companies plan a decrease or no increase at all. Hercules plans to decrease capital expenditures in 1992 by 11% to $200 million; Ethyl, 6% to $165 million; and Air Products, 3% to $492 million. Dow and American Cyanamid plan to spend about the same as in 1991—$2 billion for Dow and $385 million for American Cyanamid. On the positive side, three companies plan an increase in capital spending. In addition to PPG's 14% increase to $400 million, Du Pont plans a 9% boost to nearly $3 billion, and Rohm & Haas a 5% hike to $300 million.

Despite the modest increase in capital expenditures planned for the group, C&EN estimates industry capital spending as a percentage of sales will weigh in at a hefty 10.4% for 1992. That projection not only is based on the 4% average increase in capital expenditures for reporting companies, but also on the assumption that the four who did not respond will collectively increase spending at about the same rate. The prediction also assumes that 1992 will see a modest recovery in chemical industry sales of 4%.

For 1991, C&EN estimates that companies surveyed spent 10.7% of sales on capital projects. That figure is based on the assumption that sales grew 2% in 1991 for the 12 firms surveyed. It also assumes that capital expenditures for the group of 12 declined 11%, instead of a 3% decline predicted last year for the group (C&EN, Dec. 24, 1990). The recent highs in capital spending as a percentage of sales indicates that project commitments made during better economic times are still under way.

Although C&EN's survey points to a marginal 4% increase in industry capital spending for 1992, CMA's survey of members predicts a 10% increase in 1992. C&EN's survey and CMA's survey have disagreed in the past. Last year CMA predicted industry spending would increase 13% in 1991, but this year it has revised 1991 estimates downward to only a marginal 1% increase. Last year's C&EN survey of 1991 capital spending predicted a 3% drop, and in this year's survey the drop for 1991 looks even greater: an 11% decline.

This year's survey also predicts 1992 U.S. capital spending will increase at a faster pace than spending by responding companies worldwide. Six plan to increase spending domestically, one plans to keep spending at the same rate, and only one plans to decrease spending. PPG leads the group with a planned increase of 13% to $225 million in domestic capital spending, followed by Ethyl, with an increase of 10%. Dow plans to increase domestic spending 9% to $1.2 billion; Air Products, 8% to $364 million; and Rohm & Haas and Du Pont, 5% to $200 million and $2 billion, respectively. American Cyanamid plans to spend the same amount domestically—$285 million—as it spent in 1991. Hercules' planned U.S. spending will be down 11% to $160 million. □

German chemical giants slow U.S. spending

The three German chemical giants, BASF, Bayer, and Hoechst, forecast their 1992 capital expenditures in the U.S. will increase only 1% from this year's spending. However, only one of the three, Bayer, gives any indication of how much it intends to spend on capital projects worldwide.

In the U.S., Hoechst Celanese plans the largest increase in capital expenditures, up 10% from 1991 to $550 million. Meanwhile, Bayer, which will operate in the U.S. under the name Miles Inc. beginning in January, plans to increase spending 5% to $325 million. Only BASF plans an actual decrease in U.S. capital expenditures in 1992, down 9% to $500 million.

The combined 1% increase in U.S. spending for the three follows a 9% increase in 1991 expenditures compared with 1990 spending. For 1991, Hoechst Celanese raised capital expenditures 25% to $500 million. However, the data this year include expenditures for Celanese Mexicana, which were not included in previous years' data. BASF increased its capital expenditures 5% this year to $550 million and completed a number of projects including a textile nylon filament plant in Anderson, S.C.; a urethane specialties plant in Clemson, S.C.; and a thermoplastic polyurethane elastomer resin facility in Wyandotte, Mich. Bayer USA decreased spending 5% in 1991 to $310 million.

Bayer plans to spend $1.9 billion worldwide, down 3% from expenditures in 1991. Bayer is also the only German company that had a strong fix on actual 1991 expenditures and was willing to disclose them for C&EN's survey. The company predicts 1991 capital expenditures of nearly $2 billion, down 16% from 1990.

Because of the increase in the dollar's value, the German chemical companies will find it more expensive to finance U.S. capital expenditures with deutsche marks. Last year C&EN used a conversion rate of $1.00 = 1.5 deutsche marks. This year the conversion is $1.00 = 1.6 deutsche marks.

	1992		1991		Change from previous year	
$ Millions[a]	Total	U.S.	Total	U.S.	1992	1991
BASF	na	$ 500	na	$ 550	na	na
Bayer	$1898	325	$1962	310	−3%	−16%
Hoechst	na	550[b]	na	500[b]	na	na
TOTAL	**$1898**	**$1375**	**$1962**	**$1360**		
ANNUAL CHANGE[c]	**−3%**	**1%**	**−16%**	**9%**		

a $1.00 = 1.58 deutsche marks. b Includes Celanese Mexicana. c Cumulative change for companies reporting. na = not available.

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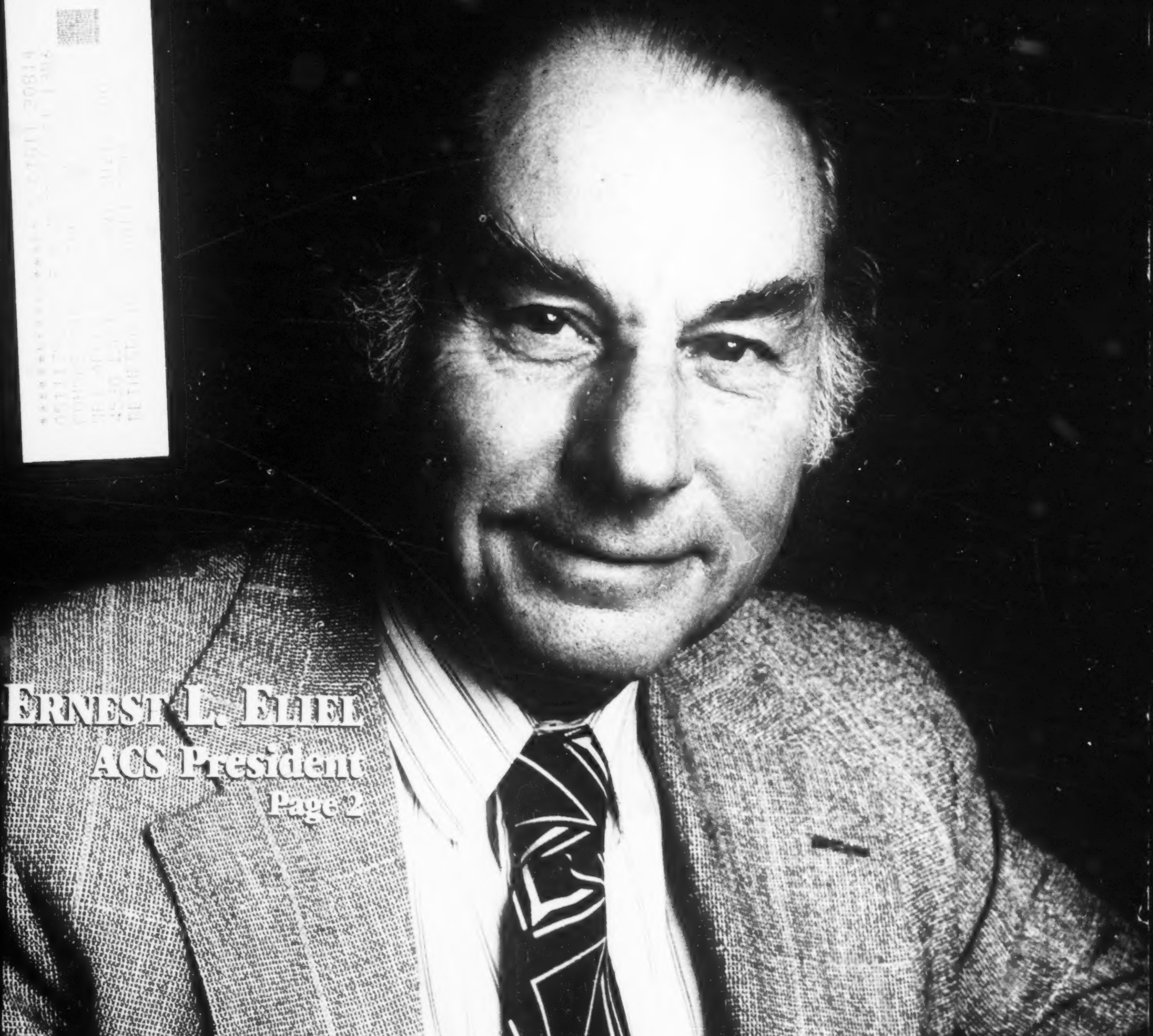
HOW NSF DIRECTOR MASSEY FARES AFTER NEARLY A YEAR IN OFFICE PAGE 9



ERNEST L. ELIEL
ACS President
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- Proposed global trade rules governing patents are criticized by representatives of chemical, pharmaceutical industries. Page 6
- Caltech researchers report first use of timed sequence of laser pulses to control a chemical reaction. Page 7
- Federal Bureau of Investigation defends its use of DNA "fingerprinting" in criminal cases against charges of misuse raised by two scientists. Page 7
- The roles of two-year colleges in science, engineering, and math education should be given increased attention, a recent NSF report urges. Page 8
- Exhibit at Smithsonian Institution's Natural History Museum chronicles impact of *Exxon Valdez* oil spill on Alaska's Prince William Sound and surrounding environs. Page 8

COVER: Photo by
Jane Hamborsky

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Business

Merger of Commerce Department's chemical office into another group upsets chemical industry leaders who feel the office has been downgraded. Page 17

Morton International is poised for growth bolstered by its strong performance in specialty chemicals. Page 18

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Pollution prevention is taking hold on all aspects of government and industry as reflected in the increasing role of legislation and the proliferation of industry programs. Page 21

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Copper circuits form directly on Teflon with new, simpler three-step additive process. Page 24

Biosynthetic route to catechol that diverts glucose from aromatic amino acid synthesis discovered in *E. coli.* Page 26

Bouyancy is key to new levitation processing method that can be done in conventional industrial equipment. Page 27

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Modernization of physical chemistry lab program funded by Pew Charitable Trusts is undertaken by consortium of selected colleges and universities. Page 29

University of Illinois' new engineering library to be built at the Urbana-Champaign campus is $18.7 million gift from the Grainger Foundation. Page 30

Meetings

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NEWS FOCUS

With nearly a year of tenure behind him, NSF director Walter Massey is ushering in changes calculated to provide greater accountability, efficiency, and effectiveness to academic research oversight. Page 9

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1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
Robert H. Marks, Director, Publications Division

PUBLISHING BOARD: Ned D. Heindel *(Chairman); Board of Directors Chairman:* Joseph A. Dixon; *President:* Ernest L. Eliel; and four members of the Society Committee on Publications yet to be appointed.

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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Graphitic tubules

The graphitic tubules described in the Science/Technology Concentrates column (C&EN, Nov. 11, 1991, page 25) may not be a new carbon form. Hyperion Catalysis International Inc. of Lexington, Mass., makes and sells carbon of apparently similar structure.

What may be of interest to C&EN readers is that the Hyperion material is made catalytically from gaseous precursors at far less drastic conditions than used by the NEC researchers. (See, for instance, U.S. Patent 4,663,230.) The literature on such catalytically grown carbons clearly shows a family of tubular carbon forms with varying carbon orientations and properties.

The Hyperion patent cited above covers as a composition of matter the morphology described as "gift wrapping" in your article.

Robert Hoch
Hensonville, N.Y.

Education in Japan

As a transcultural student myself, I relate gratefully to the keen observations and opinions expressed in the special report, "Scientific Research & Education in Japan," by Koji Nakanishi (C&EN, Dec. 2, 1991, page 30).

Aside from various informative statistics that Nakanishi compiled throughout the report, his insight and in-depth comparison of the academic, and, to a lesser extent, industrial research in chemistry in the U.S. and Japan was invaluable not only to all fellow scientists and educators in the field but also to policymakers on both sides of the Pacific.

Having experienced three different education systems from Taiwan to Singapore to the U.S. during my high school and college period, I share Nakanishi's observation that the Japanese education system—the same is also currently practiced in Taiwan and Singapore—has traditionally been more stringent at the precollegiate level than in the West (that is, from kindergarten to high school). And its mission has been primarily geared toward the preparation of taking the annual university entrance exams. Such a system does foster youngsters with great discipline and solid foundation for advanced study. However, it falls short on encouraging advanced research at the university and graduate school level due to exhaustion from passing the entrance exams and rigidly controlled proposal evaluation procedures.

On the contrary, the elementary and high school education system in the U.S. has been regarded recently as a failure in the public's eyes. Nevertheless, the social attitude toward freedom and choice here in the U.S. dominates the fundamental philosophy of its higher education system, which effectively emphasizes individuality and creativity, and promotes new visions and ideas in all areas of scientific research.

By comparing and understanding the differences and similarities of various education systems in other countries, perhaps a better framework of precollegiate education and advanced research policies here in the U.S. may be formulated in years to come.

Wilhelm W. Wang
Princeton, N.J.

Abuse from interviewers

Many of us, men and women alike, face a kind of abuse when we start seeking employment. Molly Gleiser's letter (C&EN, Nov. 4, page 4) about her noninterview represents an extreme case of such abuse from a person who is placed in an advantageous position. My personal experience of having an interview after the position was filled in order to let some company managers dine with me for two days in a number of expensive restaurants, and of having a "lady" interviewer intimidate me, falls beyond the norm. Perhaps for elimination purposes, a "gentleman" interviewer from another chemical company opted to talk about areas where I lacked experience, pounded me with questions, and enjoyed my helplessness.

Probably nothing can be done against the persons who enjoy intimidating and harassing a starter. These abuses are often carried out without any corroboration. These are traumatic and cannot be forgotten. It is unknown to us if there are mechanisms (from the employers' side) to track the abusive behavior of the interviewers. At this point, like Gleiser, we are left with only the option to wish that the abuser will "take a bow" in the future. This never happens! However, the bright side is that the abusers are outnumbered by nice and kind people in every institution or company.

Bhajendra N. Barman
Beaumont, Tex.

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Pollution Prevention Becoming Watchword for Government, Industry

■ ***EPA study of progress on reducing pollutants cites growing role of legislation, proliferation of industry programs***

David J. Hanson, C&EN Washington

Just as the decade of the 1980s will be remembered for efforts to clean up hazardous waste, the 1990s may be the decade of pollution prevention. Although the public has caught onto this only recently, industry has been working on it for some time. A new report from the Environmental Protection Agency demonstrates how much this concept is taking hold on all aspects of government and industry.

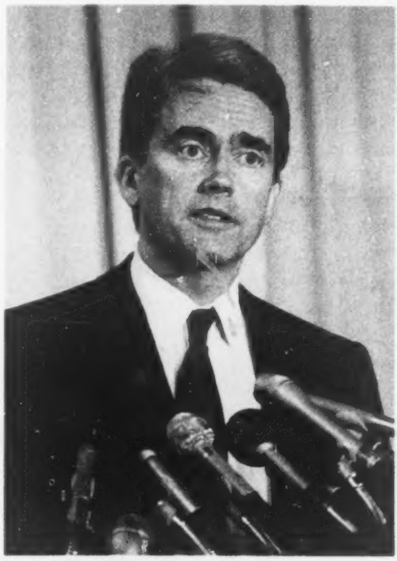
EPA Administrator William K. Reilly sees the change as falling back on common sense, a part of the evolution of environmental protection. "Incorporating pollution prevention into everyday decisions is a major undertaking," he says. "To succeed it will require a better and more sophisticated understanding of the environment."

Much pollution prevention is aimed at manufacturing. Although 32% of carbon monoxide emissions and 31% of volatile organic chemicals emissions to the atmosphere derive from transportation, the biggest play is given to industrial emissions. This is partly because they can be more easily measured and regulated.

In fact, it is such programs as the Toxic Release Inventory of the 1986 Superfund Amendments & Reauthorization Act and the reporting requirements of the Resource Conservation & Recovery Act that tell the public and government what manufacturers are releasing into the environment. The toxics inventory is also one of the few sources of data on what companies are doing to reduce the generation of pollution. More information will become available over the next few years as the 1990 Pollution Prevention Act comes into play.

Because the source reduction reporting on the inventory is voluntary, however, comparatively few facilities have provided the information. EPA says just 11% have indicated pollution prevention activities and that the combination of adjusted numbers and actual reductions makes any trends in pollution prevention unclear. Each year of the inventory, which began in 1987, has generated more prevention data, but new regulations for this year will make such reporting mandatory.

Manufacturers are already moving to make pollution prevention a priority of their own. The EPA report looks at several major industrial associations and the impact they are having on emissions from their members. The Chemical Manufacturers Association, for instance, launched its Responsible Care program in 1988 to improve the industry's management of chemicals. Although Responsible Care does not address pollution prevention directly, one of the program's codes of management practices is on waste and release reduction.



C&EN staff photo

Reilly: falling back on common sense

Other industry associations with environmental principles mentioned in EPA's report include the American Petroleum Institute (API), which has a set of principles its member companies are expected to follow. One of these directly addresses pollution prevention by requiring members to commit to reducing overall emissions and waste generation. API has published some reports containing pollution reduction information. Both the National Paint & Coatings Association and the National Electrical Manufacturers Association provide information to their members on chemical release reduction.

To highlight some individual efforts in pollution prevention, the EPA study looks at what two chemical companies have accomplished. Dow Chemical's Waste Reduction Always Pays program, started in 1986, is credited with cutting its emissions of Toxic Release Inventory chemicals 21% from 1987 to 1989. Dow reports that more than $3 million of special capital funds have been spent on pollution prevention projects over the past three years. EPA also cites Dow's Chem Aware program, which is designed to inform Dow employees and customers on how best to purchase, process, handle, and dispose of Dow products.

EPA mentions Whyco Chromium of Waterbury, Conn., a small company that has been innovative in reducing chemical pollution. EPA points out that the company spent more than $2 million on pollution control in 1990, and spent an increased amount on research programs. The company developed a new method to make its metal-coated products that greatly reduces the amount of cyanide bath solution used.

Although companies can do a lot on their own to reduce pollution, the force that is really moving pollution prevention forward is the federal government. Because of increased pressure on Congress to reduce pollution, several recent laws have pushed pollution prevention to the fore. And federal agencies other than EPA have started to mandate pollution reduction programs.

First among pollution reducing laws is the 1990 Pollution Prevention Act, which goes into effect later this year. The law will force companies to focus on ways to reduce emissions rather than treat wastes. Among other things, the law establishes a source reduction clearinghouse on pollution prevention information; provides for the developing, testing, and disseminating of auditing procedures designed to identify source reduction opportunities; sets up standard methods to measure pollution reduction; expands the toxic release inventory reporting requirements to include questions about source reduction and recycling; and requires EPA to report to Congress on the progress of the reduction programs. Overall, the Pollution Prevention Act has the potential for creating many changes in the chemical industry.

Other laws affecting source reduction are the 1990 amendments to the Clean Air Act; Federal Insecticide, Fungicide & Rodenticide Act; and the Toxic Substances Control Act. The recently passed air pollution law, for example, requires EPA to conduct an engineering research program to develop new technologies for air pollution prevention. And it requires that EPA take into consideration process changes or material substitutions when setting emissions standards for hazardous chemicals. The idea that EPA could force a facility to change its process or materials to reduce emissions worries some chemical industry officials.

In addition to EPA, other federal entities are moving into pollution prevention. The Department of Defense is the largest of these, with more than 1000 major installations worldwide. DOD's major pollution project is the 1989 Directive on Hazardous Material Pollution Prevention. It puts a priority on not using hazardous materials to begin with, and if they are used, it recommends recycling or reusing as much as possible. DOD has also developed its own pollution prevention programs, as industrial companies have, as well as its own R&D program for reducing generation of hazardous waste. Another federal department with a major pollution prevention program mentioned in the report is the Department of Energy.

Other major players in the pollution prevention arena are the states. They have been in the lead on emissions reporting and continue to maintain this lead. The EPA report says there are presently more than 50 state laws that contain some aspect of pollution prevention, more than half of which were enacted in 1990. Most require some sort of facility planning requirement, by which a company must file a written pollution prevention plan. Requirements for these plans vary from state to state, but most include items such as a description of current practices to eliminate or reduce generation of hazardous pollutants, information on the amount of waste generated per unit of production, a list of pollution prevention options considered economical or technically feasible, and specific pollution prevention goals. Other pollution prevention measures adopted by states mentioned in the report include imposition of taxes and fees on hazardous-waste generation, prohibition of the use of certain chemicals such as heavy metals or chlorofluorocarbons, requirement of emissions reporting, and establishment of awards for successful industrial pollution prevention programs.

CMA survey shows chemical facilities are polluting less

Millions of tons	Number of facilities	Liquid waste	Solid waste	Total
1981	536	304.4	4.9	309.3
1982	528	289.5	3.0	292.5
1983	722	311.3	3.1	314.4
1984	725	272.2	1.8	274.0
1985	681	210.2	2.2	212.4
1986	529	216.2	1.3	217.5
1987	552	211.6	1.6	213.2
1988	582	213.2	1.6	214.8

Source: Chemical Manufacturers Association

Even universities are becoming more involved in the pollution movement. Many are providing technical assistance to local businesses in the form of on-site pollution assessments and workshops, the EPA study says. As faculty gain more experience, curriculum changes and research topics in pollution prevention also are increasing. Finally, with some encouragement from expanded environmental regulations, universities are working on reducing the volume of their own hazardous waste by using more microscale methods in labs.

To make the issue of pollution prevention even more complicated, local governments are also getting involved. The EPA study says that city and county governments in California, particularly, have played a major role in industrial pollution prevention. Local governments can offer more flexibility to deal with specific problems than can federal regulations, it says, and they are often in a better position to identify the needs and limitations of local facilities. Common elements in local programs are educational information to local companies, technical and financial assistance, and permits and licenses to force local companies into waste minimization.

The last section of the report looks at sources of pollution other than manufacturing. EPA has not developed any specific pollution prevention strategies for nonindustrial pollution, although the agency is working with other federal departments to do so. These areas include agriculture, where the greatest concerns are runoff of agricultural chemicals and contamination of groundwater; the whole area of energy production and use (although some of this is covered under the Clean Air Act amendments); transportation; consumer awareness of pollution prevention; and pollution by municipalities.

EPA's report, titled "Pollution Prevention 1991: Progress on Reducing Industrial Pollutants," is long on simplistic descriptions of this complicated field and short on specific, detailed examples or data. Admittedly, specifics on source reduction have only begun to be collected by many companies, but chemical companies in particular are anxious to talk about their successes in pollution prevention. The fact that it takes a 200-page report to give a brief overview of pollution prevention activities to date only serves to strengthen the conviction of how important this strategy will be over the next decade. ☐

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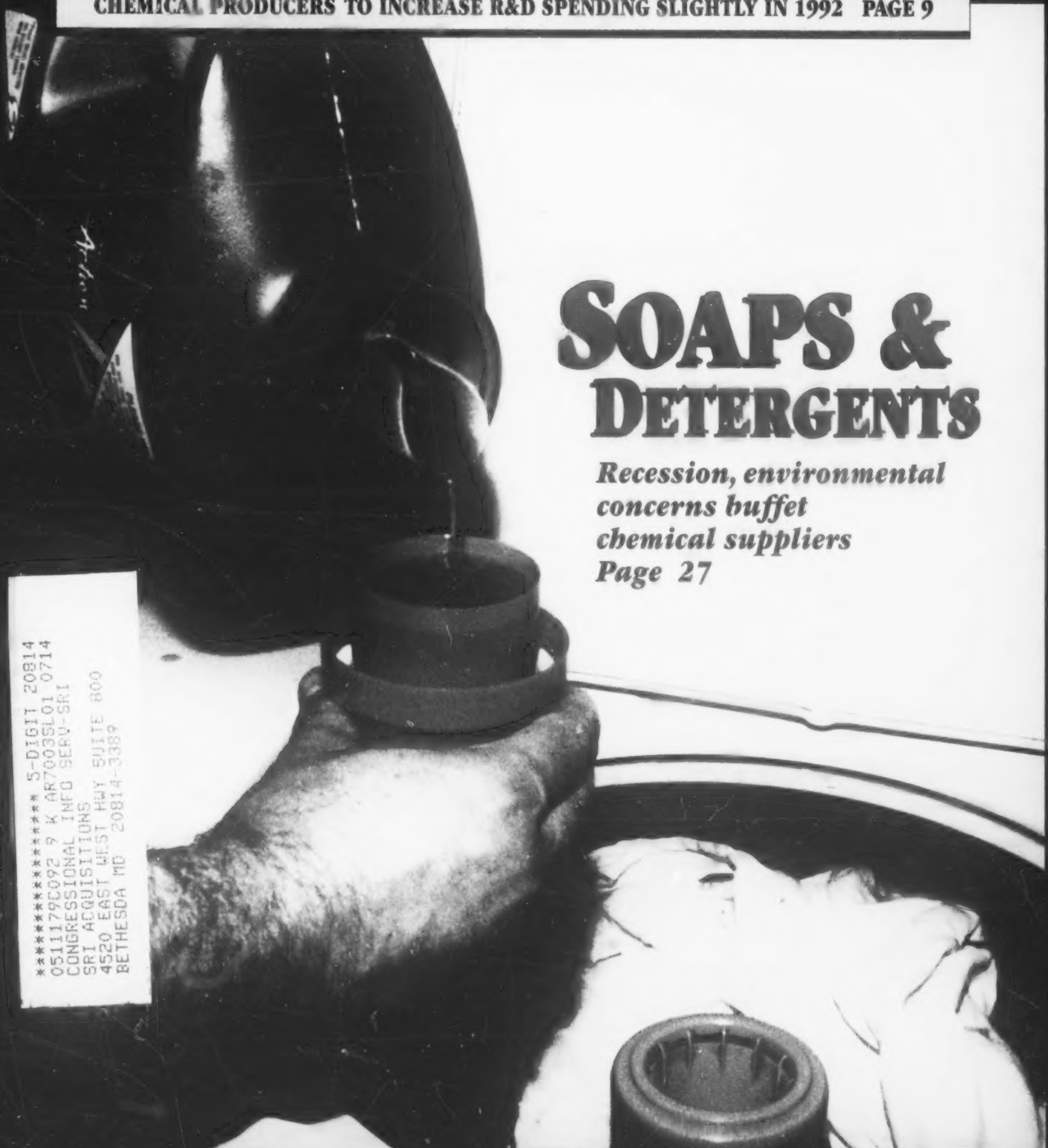

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Recession, environmental concerns buffet chemical suppliers
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NEWS OF THE WEEK

- Although labeled a failure by critics in the U.S. and Japan, President Bush's recent trip to Japan is called a success by chemical executive who was in U.S. delegation. Page 4
- French scientists have crushed buckminsterfullerene to diamond by applying high pressure at room temperature. Page 5
- Potential cure for cystic fibrosis using a genetically engineered adenovirus has been worked out by researchers at NIH. Page 5
- Oceanographic research ship begins international study of environmental damage to Persian Gulf region caused by massive oil spill during the war. Page 6
- Bacteriorhodopsin-based photocell developed by Japanese chemists reacts to instantaneous changes in light intensity, could provide basis for development of artificial vision devices, optical computers. Page 6

COVER: Photo by C&EN's Ernest L. Carpenter

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BUSINESS

Major U.S. chemical firms plan a 4% boost in R&D spending on average this year, following a decrease of 2% in 1991, according to C&EN's annual survey. Page 9

Western European chemicals production will grow modestly in 1992, at least better than last year, forecasts CEFIC, the European Chemical Industry Council. Page 12

GOVERNMENT

Global environmental revolution must be initiated, says Worldwatch Institute, as a prerequisite for the UN's June Earth Summit meeting, which is expected to develop an action plan for sustainable development. Page 18

SCIENCE/TECHNOLOGY

Scientists can view surface atoms on the move via a transmission electron microscope technique developed by University of Illinois researchers, thus enabling them to observe microstructural changes occurring during a processing operation. Page 21

Unusual backbone structures can be incorporated into proteins using a biosynthetic method worked out by chemists at the University of California, Berkeley. Page 22

PRODUCT REPORT

The recession and concern about the environment are affecting virtually every move made by U.S. soap and detergent manufacturers and their suppliers. Page 27

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Looking to the future

I wish to congratulate John Verkade on his election as director of Region V. As one of the candidates in the recent election, this was my first opportunity to observe, firsthand, ACS politics at work on the national level. Several aspects of the election were disappointing, but the small number of ballots cast in the election was particularly so. I hope this is not an indication of member apathy, but simply of the fact that our members are too busy to take time to return their ballots. Also, even though our society has strict regulations about the use of society publications in campaigning, these are often difficult to enforce. All candidates are certainly entitled to equal and fair treatment, and those who run the elections should make every effort in the future to ensure this.

Our society would only suffer with an extended investigation in regard to this election, and our energies can be better directed for the good of the society. Let's put this election behind us and look to the future. The society and the chemistry profession have several pressing problems, which, if not addressed, could result in grave consequences for our profession.

Although I will not be serving on the ACS Board of Directors, I will continue my activities as a councilor, as a member of the Division of Professional Relations, and as a member of the Economic Status Committee, to bring about vitally needed changes to improve the economic and professional status of our members. As the economy of our nation continues to falter, our task becomes even more arduous. My activities are not tied to title, but to my continuous concern about the responsibility of ACS to its large majority of members whose interests we must address. I want to thank my supporters for their help and I ask them to put this election behind them and help me in my efforts to improve our society.

E. Ann Nalley
Professor of Chemistry
Cameron University

Michael Faraday

I found your article on Michael Faraday (C&EN, Sept. 23, 1991, page 17) very interesting. Faraday was a great man and a great scientist and it is impossible to remember all his discoveries and ideas, but I would like to add a further contribution to demonstrate his widely skilled genius.

Some years ago I published a review on historical aspects of dust explosions. During my research, I came across an article by Faraday and C. Lyell, "Report on Explosion at the Haswell Collieries," published in 1845 in *Philosophical Magazine.*

At that time, Faraday's expert help was often called for in court. As a matter of fact, the article I found is a report presented in court and referring to the explosion in Haswell Collieries, which caused 95 deaths.

Faraday was the first scientist to realize that the explosions in mines, previously attributed only to firedamp, could also be caused by coal dust.

In retrospect, Faraday's work in this field might seem insignificant compared with his important, well-known discoveries, but it helped to make the scientific community and the public realize that solid materials dispersed as dust clouds in air can explode even without flammable gases.

Faraday first explained the phenomena and then contributed to the development of safety measures not only in mines, but also in every industry where flammable dusts are used.

It was very moving to read Faraday's original paper. Today his remarks and perceptions are found in textbooks on dust explosions as axioms.

Paolo Cardillo
Stazione Sperimentale per i Combustibili
San Donato Milanese, Italy

In school (Arbor View Elementary, Glen Ellyn, Ill.) my challenge program teacher, Mrs. Tucker, asked us to pick a creative problem solver to write a report on. I picked Michael Faraday. I started to get interested in him when I read your article, "Michael Faraday Feted on 200th Anniversary of His Birth." You guys are awesome article writers! I thank Stu Borman for writing a very interesting and thorough article.

For my report, I also got some more

Correction

- Jan. 6, page 32: ACS cannot continue to send C&EN and journals after Feb. 29, not March 31, to those members whose 1992 dues and subscriptions are not received by Feb. 1, not March 1.

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Chemical Industry R&D Spending To Increase Slightly

■ ***Twelve major chemical producers plan 4% hike in research expenditures this year, translating to 2% rise in constant-dollar terms***

Marc S. Reisch,
C&EN Northeast News Bureau

C&EN's just-completed survey of 15 major chemical companies and nine diversified companies that produce chemicals show that most plan to increase research and development spending modestly in 1992.

However, a proposal expected in President Bush's economic recovery package this month making an R&D tax credit a permanent part of the tax code might help boost 1992 R&D spending beyond the survey's projected 4% increase for 12 chemical companies (three of the 15 firms surveyed haven't released 1992 projections). For now, though, the economy has forced companies to restrain increases in their R&D expenditures and direct more effort to achieve short-term product development goals.

According to the survey, the 15 chemical companies estimate that their R&D spending in 1991 decreased an average of 2% from the year before. In recent years, average annual increases for the group were much greater: In 1990, the R&D spending for the group increased 10% over the previous year, 8% in 1989, 9% in 1988, and 8% in 1987.

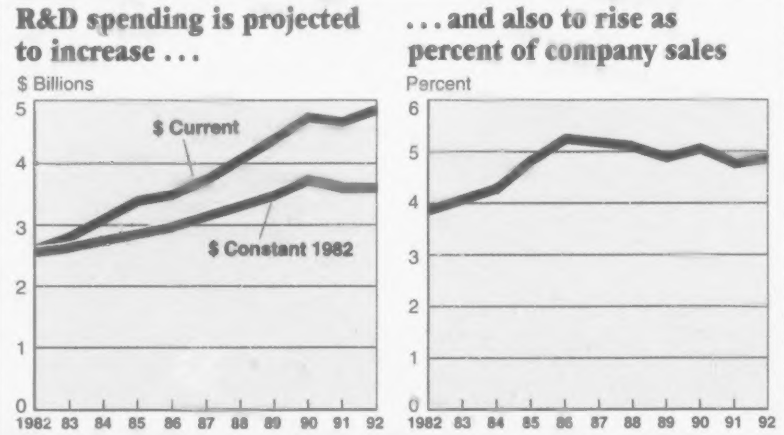
As the economy soured, and the business outlook for individual companies changed, many companies' priorities changed, too. Of the 15 chemical companies surveyed, Du Pont, W. R. Grace, Hercules, Olin, and Union Carbide have reorganized themselves. Over the past year they have sold or plan to sell some important businesses, and formed or plan to form joint ventures. Du Pont formed a multi-million-dollar pharmaceutical joint venture with Merck; Grace plans to spin off its organic chemicals business; Hercules will form a flavors joint venture with Imcera's Fries & Fries unit; Olin has reached agreements to sell a number of small chemical businesses; and Carbide has formed a joint venture with Mitsubishi to operate its graphite business and recently announced the spin-off of its industrial gases division into an independent company.

The R&D dollars devoted to a sold or joint-venture operation can no longer be included in a company's account of R&D. Also, few have made acquisitions to balance both the revenues and R&D commitments lost.

Although companies sell and shuffle around their businesses even in the best of times, those actions can have a strong impact on the R&D data they report. For instance, Du Pont's 1991 data exclude Du Pont pharmaceutical R&D because of the formation of the Du Pont Merck Pharmaceutical joint venture as of January 1991. Had Du Pont been able to include pharmaceutical research in 1991 data, a Du Pont spokesman says that the average increase last year over the previous year would have been 6%. (The other 14 companies showed an average 2% increase in R&D in 1991 compared with 1990.)

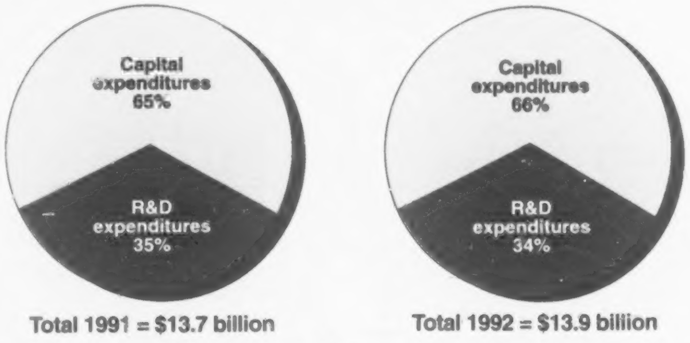
Even among the diversified companies in C&EN's survey, individual companies' changes in fortune have a measurable impact on the group's R&D spending. IBM's well-known sales and competitive problems forced the giant to cut its budget to \$6.5 billion in 1990 from \$6.8 billion in 1989, causing the table of diversified companies to show a 1% average decline in 1990. IBM's subsequent R&D budget drop in 1991 to \$6 billion further limited the diversified group's increase to 4% in that year and to a projected 1% for 1992. On the other hand, AT&T's purchase of NCR added significantly to its 1991 R&D budget of \$3.1 billion. Without it the 1991 average increase for the diversified group of companies would have been much lower.

The economic upheavals affecting so many individual companies are bound to have an effect on future-oriented growth and development for the chemical industry. C&EN projects that R&D as a percentage of future-oriented



Note: For 15 companies listed on page 11. **Sources:** C&EN surveys and estimates, Battelle

R&D down as percent of future-oriented spending



Note: Based on C&EN surveys and estimates of 12 major chemical companies listed on page 11 (Arco Chemical, Lubrizol, and Petrolite are excluded because they were not included in the 1991 capital spending survey).

spending (combined R&D and capital expenditures) will decline one percentage point in 1992 compared with 1991 to 34%. The data are derived from a group of 12 companies for which C&EN tracks both capital and R&D expenditures. The 10-year high for the group was in 1987, just as the chemical industry experienced a boom in sales and profits spanning 1986 to 1988. In 1987, R&D as a percentage of future-oriented spending was 39%.

Still, in these relative terms, R&D in 1992 will not drop anywhere near the 10-year low of 29% of future-oriented spending in 1982, during the last most serious recession. This year actually promises a recovery in R&D spending for the 15 chemical firms surveyed and the chemical industry as a whole. The Chemical Manufacturers Association projects a 5% increase in chemical-related R&D spending in its recent survey of member companies, compared with C&EN's projected 4% increase. Both of these forecasts are higher than Battelle's forecast of a 3.2% increase to $80.5 billion for all industry R&D spending in 1992. The Columbus, Ohio-based research organization also estimates that all industry spending after inflation will show a real increase of less than 1% compared with a real increase of nearly 2% when its inflation data are applied to C&EN's survey results.

Jules J. Duga, senior R&D policy analyst for Battelle, argues that as corporate profits suffer, industry sees R&D as a candidate for short-term curtailment. As a result, R&D directors are putting more emphasis on short-term research projects where they can make a case for R&D's impact on profits. In Duga's opinion, "The environment that permits greater rewards for short-term financial results, rather than technological innovation, will continue to have an adverse effect on R&D investment."

Petrolite's vice president of technology, Ralph J. Churchill, makes a convincing argument for R&D directed at satisfying immediate customer needs. "To service our customers in today's market we feel there is more need to fund field support than research." Churchill says Petrolite has begun to view itself as a service company. "People are paying us for the performance of our products, not for a specific chemistry," he says.

Churchill notes that Petrolite has renamed its R&D department a technology department, because the latter term "encompasses more than the development of new products." He says the company has not given up its basic research, but has put more effort into applying that research to customer needs. The company defines R&D as basic research—it does not include technical support and field assistance to customers in the R&D numbers it reports. As a result, the company's R&D budget has moved in a narrow range between $11 million and $13 million since 1983. But Petrolite's expenses for technical assistance in support of its customers has ranged from $20 million to $21 million for the past several years, says Churchill. In 1992, the company plans to devote $23 million to technical assistance.

The reorientation of R&D spending in direct support of customers is not a new movement among the nation's chemical companies. Companies emphasize the reorientation only because they must show they are making efforts to bolster profitability in a difficult economy. Battelle's Duga says the economic pressures on R&D directors has made them keenly aware, on the one hand, of the requirement to satisfy the need for R&D that aids corporate sales, and on the other, of the need to conduct the sort of "R&D investment necessary for long-term profit and survival."

Dow Chemical's vice president of R&D, Fred P. Corson, notes that all of Dow's research "has some target for commercial opportunity," though he admits the targets are not always achieved. About 20% of Dow's R&D effort in the company's core basic, industrial, and specialty chemicals, and in its plastics businesses, is aimed at developing new technology for new product lines—the type of R&D that Duga would say is necessary for long-term profit and survival. The remaining 80% goes to support and expand existing businesses with process support and product research leading to product line extensions.

Whether Dow or Petrolite have found a good balance for their respective R&D budgets is another question. But how these and other chemical companies decide to fund and increase their R&D efforts is bound to have an impact on the bottom line. As it appears now, chemical R&D growth is modest and may remain modest in the future until chemical industry sales and profits improve or the government changes the rules affecting R&D tax credits.

Therefore, significant growth in dollars directed at either serving customers or developing the brand new products necessary for long-term survival, may come if the U.S. government decides soon to extend R&D tax credits permanently. Many in the research community are hoping that President Bush's budget proposals expected later this month will contain such a permanent tax credit. According to Kenneth R. Kay, executive director of the Council on Research & Technology (Coretech), a 20% credit on increases in R&D spending is scheduled to expire by midyear. Coretech is a Washington, D.C.-based coalition of companies and universities committed to promoting a strong U.S. R&D policy, says Kay.

As it exists now, Kay points out, the tax credit boosts U.S. R&D spending 6

Major chemical companies plan 4% rise in R&D spending this year

$ Millions	Planned 1992	Actual 1991	Planned 1991	1990	1989	1988	1987	1986	Change from previous year 1992	Change from previous year 1991	R&D spending as % of sales 1992	R&D spending as % of sales 1991
CHEMICAL COMPANIES												
Air Products[a]	$ 85	$ 80	$ 79	$ 72	$ 71	$ 72	$ 57	$ 61	6.3%	11.1%	2.7%	2.7%
American Cyanamid	540	480	479	461	407	365	314	278	12.5	4.1	11.0	10.2
Arco Chemical	63	60	na	59	52	39	29	32	5.0	1.7	2.1	2.1
Dow Chemical	1230	1,160	1180	1,136	873	772	670	605	6.0	2.1	5.8	5.7
Du Pont[b]	1237	1,245	1220	1,428	1,387	1,319	1,223	1,156	−0.6	−12.8	5.2	5.4
Ethyl[c]	69	69	68	65	61	59	50	47	0	6.2	2.6	2.7
W. R. Grace	153	150	150	148	125	119	107	94	2.0	1.4	2.1	2.2
Hercules	na	86	na	92	79	74	74	71	na	−6.5	na	2.6
Lubrizol	86	79	na	74	70	65	62	51	8.9	6.8	5.5	5.3
Monsanto	na	640	na	612	598	575	557	523	na	4.6	na	6.9
Olin	50	50	na	66	66	58	62	56	0	−24.2	1.8	1.9
Petrolite[d]	13	11	12	12	12	12	12	12	18.2	−8.3	4.0	3.6
PPG Industries	225	225	250	236	249	239	227	204	0	−4.7	3.5	3.6
Rohm & Haas	195	185	185	178	175	156	142	133	5.4	3.9	6.4	6.4
Union Carbide	na	190	200	191	181	159	159	148	na	−0.5	na	2.4
TOTAL	**$3946**	**$ 4,710**	**$3823**	**$ 4,830**	**$ 4,406**	**$ 4,083**	**$ 3,745**	**$ 3,471**			**4.9%**	**4.8%**
ANNUAL CHANGE[e]	**4%**	**−2%**		**10%**	**8%**	**9%**	**8%**	**2%**				
DIVERSIFIED COMPANIES												
Allied-Signal[f]	650	650	700	721	603	647	667	734	0	−9.8	4.9	5.1
AT&T Bell Labs	na	3,100	na	2,433	2,652	2572	2,453	2,278	na	27.4	na	8.1
Eli Lilly	na	800	na	703	605	512	466	427	[illegible]	13.8	na	15.0
FMC	140	136	140	158	150	144	132	146	2.9	−13.9	3.5	3.5
IBM	6000	6,000	na	6,500	6,827	5,925	5,430	5,221	0	−7.7	8.1	8.4
Merck & Co.	na	1,000	na	854	751	669	566	480	na	17.1	na	12.7
Morton International[f,g]	60	59	60	48	38	35	31	29	1.7	22.9	3.0	3.1
Procter & Gamble[g]	na	786	na	693	628	615	549	479	na	13.4	na	2.9
Schering-Plough	480	425	420	380	327	298	251	212	12.9	11.8	13.5	12.4
TOTAL	**$7330**	**$12,956**	**$1320**	**$12,490**	**$12,581**	**$11,417**	**$10,545**	**$10,006**			**7.6%**	**7.5%**
ANNUAL CHANGE[e]	**1%**	**4%**		**−1%**	**10%**	**8%**	**5%**	**13%**				

a Fiscal year ends Sept. 30. **b** All figures exclude Conoco. 1991 and 1992 figures exclude pharmaceutical research now part of Du Pont Merck Pharmaceutical Co. **c** 1989, 1990, 1991, and 1992 figures adjusted to reflect spin-off of Tredegar Industries in July 1989. **d** Fiscal year ends Oct. 31. **e** For those companies reporting. **f** Includes all company-financed R&D but excludes contract R&D. **g** Fiscal year ends June 30. **na** = not available.

to 8% beyond what private sources would otherwise commit to R&D. Of the $60 billion he says is spent on privately funded R&D in the U.S., the tax credit returns $1 billion to industry, but in so doing, results in a net increase of $4 billion directed to R&D. Coretech would like to see Congress and the Administration make the tax credit permanent, instead of extending its provisions for six months to a year at a time. This would go a long way toward increasing R&D spending, he says, because companies could plan their R&D budgets mindful of the credit on increased R&D spending.

Dow's Corson says the R&D tax credit "must be long term and stable to give us an incentive" to increase R&D. Short-term renewals make it "impossible to make a decision based on short-term tax law," and "in no way influences the amount we spend on R&D."

Robert B. Hill, associate director of taxation for the Chemical Manufacturers Association, says CMA would support a proposal to make the R&D tax credit a permanent feature of the tax code. In addition, CMA also would like Congress and the Administration to make permanent a rule that allows U.S. companies with foreign sales to take a credit for some, but not all, of the increase in their domestic R&D that might otherwise be denied because it supports overseas sales. Hill argues that the credit to domestic research that aids overseas sales not only would benefit the growth of U.S.-based research, but also would help maintain the U.S. chemical industry's stature as the world's largest chemical exporter.

In fact, says Corson, Dow would "be happier with a lower credit" on total R&D instead of just on the increase. If that were to happen, adds Corson, Dow "would probably do even more R&D in the U.S." Coretech's Kay says that such a blanket credit is unlikely to happen, though "from a policy perspective, Dow is right." Kay believes industry would go along with the permanent tax credit for R&D increases and a reasonable rule on the treatment of domestic R&D allocated to overseas sales. Congress, he thinks, would go along with a permanent limited tax credit, but not with a credit on all privately funded R&D because of the cost to taxpayers. ☐

Modest growth forecast for European chemicals

According to Richard Freeman, chief economist of ICI in the U.K., "1992 is expected to be a better year for the industry than 1991—but that's not saying very much."

As chairman of the economic appraisal committee for the U.K.'s Chemical Industries Association (CIA) and of the economic outlook working party of CEFIC, the European Chemical Industry Council, in Brussels, Freeman had little encouraging news for CIA's seventh annual Business Outlook Conference in London earlier this month. On tap for the year: "slow recovery" for the U.K. chemical industry, a report echoing the "slight improvement" predicted by CEFIC economists for the Western European industry in 1992.

CEFIC's forecasts, compiled at the end of November, indicate a 2% growth in production over 1991 for the European chemical industry. However, such growth assumes a considerable increase in exports. "In view of the weakness of the U.S. economy, slower growth in Japan, and weak growth in Europe itself, there is some doubt that the forecast can be achieved," CIA cautions.

After a flat year, compared with 1990, the U.K.'s chemical industry is looking for production to grow 2% this year, Freeman says. In other Western European countries, chemical production is also weak, with no sign of any recovery. Even in Germany, which avoided recession earlier as production boomed to meet the strong demand caused by unification, chemical production is slowing. Germany's chemical industry had a strong first half in 1991, but production began falling in the second half. Very little growth is expected in the first half of 1992, and the second half is predicted to be flat or show just a little growth in production.

Last year, most of CEFIC's member countries were expecting an acceleration in exports and a deceleration in imports of chemicals. In fact, the reverse occurred. "They have made the same mistake for 1992," Freeman says. For example, for 1992, exports are forecast to accelerate from 1.4% to 3.3% over last year. Import growth is also expected to accelerate—from 3.9% to 4.5%.

The forecasts for chemical demand show considerable differences among countries. The growth in demand in Germany is expected to slow down sharply, and is forecast to weaken slightly in Belgium. A strong pickup in the growth rate is forecast in Spain. However, CIA believes that the chemical demand forecasts are also on the high side, and probably will not make the 2.6% growth predicted. As Freeman points out, "Whatever happens this year, there can be no doubt that the general economic background for the chemical industry in 1992 is less than buoyant."

Outlook for chemicals upbeat despite dismal 1991

% change in chemical production	1989–90 (actual)	1990–91 January 1991 forecast	1990–91 December 1991 revised forecast	1991–92 (forecast)
Belgium	5.5%	4.0%	0.5%	3.4%
France	1.3	2.5	2.1	3.0
Germany	2.0	2.0	2.5	2.5
Netherlands	1.5	2.0	−2.0	0
Italy	1.5	0.4	−1.5	1.5
Spain	3.5	3.0	−3.0	2.0
U.K.	0.6	−1.0	0	2.0
TOTAL[a]	**2.0%**	**2.0%**	**0.3%**	**2.0%**

[a] For all of Western Europe. **Source:** European Chemical Industry Council (CEFIC)

The fall in profits in 1991 and the relatively weak demand outlook for 1992 are again expected to constrain capital spending by the industry in most countries, after cuts in spending in 1991 from 1990.

In the U.K., for example, companies cut back capital expenditures 15% from levels in 1990, compared with a drop predicted a year ago of 10%. Continuing weak demand is likely to see another sharp fall in spending by the U.K. chemical industry this year—about 6% in volume. Total Western European chemical capital spending fell about 2% in real terms in 1991, and a further fall of about the same amount is expected this year. Large declines are forecast in Belgium and the Netherlands, and spending probably also will decline in France and Italy, or be flat at best.

Chemical employment is forecast to be flat or to fall about 2% (Belgium and Spain are the exception, with chemical employment in these two countries expected to show some expansion).

Looking specifically at U.K. chemical industry performance, Freeman reports that production was flat in 1991, an "improvement" on the 1% drop from 1990 production CIA predicted a year ago. Some of that may be statistical confusion, however; "given the state of the statistics, it would not be surprising to see the index revised down to a fall of 1%" after all, he says. Imports were up 1%, exports up 3.5%, and domestic demand down 1.5%.

According to the CIA economics panel, the reason the U.K. industry held at least flat was almost entirely because of the strength of the pharmaceuticals industry—without that, production would have fallen 2.5%. For this year, output in the U.K. is expected to grow about 2%—a figure that has been revised downward from 2.5% just since late November because of continuing sluggishness in the U.K. economy—spurred by growth in pharmaceuticals, and by some recovery in paints, dyes, and plastics.

A glimmer of hope of recovery for the U.K. industry also comes from David Ingles, senior chemicals analyst at London-based stockbrokers James Capel. "Although 1992 will be a difficult year, there are some reasons to believe that improvements will start this year," he says.

These reasons include:

- People tend to concentrate on petrochemicals and plastics, but these make up only 37% of the global industry—other sectors are more recession-resistant and less cyclical, and currently more profitable to producers.
- Company balance sheets generally are in good shape, cash-rich, for example, or showing debt-to-equity ratios of a healthy less than 50%.
- Perhaps most important, unit labor costs have fallen at chemical companies—productivity is rising sharply, even though output is down or flat. "Improvements are coming through already, so that when output picks up, there will be a useful positive contribution to profits," Ingles says. "There is reason to believe the worst is over, as far as company profits are concerned."

Patricia Layman

C&EN staff photo

SOAPS & DETERGENTS

Susan J. Ainsworth, C&EN Houston

The recession and growing public concern over the environment are two factors that now figure into virtually every move made by U.S. soap and detergent manufacturers and their suppliers.

Of more concern than any particular piece of legislation affecting the soap and detergent industry, "the 'green' movement is really the major concern down the road," says J. G. (Jim) Johnson Jr., business manager for α-olefins at Chevron Chemical, Houston, referring to increasing environmental issues. "Everyone in the industry is sensitive to that," adds George Elling, market development manager for Union Carbide's surfactant business. End users "want to work with environmentally safe products."

Concern about the environment is leading the industry to develop environmentally sensitive products, which are increasingly being sold in recycled packaging material to meet regulatory requirements and satisfy consumer demand, according to a Department of Commerce report, "Cleaning Preparations and Cosmetics," released this month. A case in point: In recent years the industry has turned to concentrated detergents that are both more powerful and require less packaging material.

Environmental developments as well as changing consumer needs will create global demand during 1992 for new functional raw materials that improve the performance of detergent products, says Kenneth F. Schoene, director of performance chemicals for BASF Corp. "As a result, the role of surfactants, polymers, and other additives in laundry and cleaning products will become more critical, with formulations evolving at an increased rate," he says.

In addition, companies that supply the soap and detergent industry are being called upon to prove that the ingredients they have been supplying are indeed environmentally sound enough to continue in their roles.

The upshot is that more research and development will be needed to meet both domestic and global competition and proliferating environmental regulations, according to the Commerce report. Those companies that can come up with the products that will help their customers deal with these immediate market challenges will likely come out on top.

Given the twin pressures of the recession and the green movement, it's no surprise that the soap and detergent industry did not have a year worth bragging about. The value of industry shipments of soaps and detergents increased only 3.2% to more than $14 billion in 1991, according to Commerce. In constant dollars, growth was only 2.7% above 1990.

Delayed introductions of new products because of the general recessionary period may have been one factor limiting industry growth this year, notes Nicholas C. Fanandakis, market manager for cleaning products at Du Pont. And because the economy continues to suffer, "you may find companies who will delay launches planned in 1992 until the end of this year or push them into 1993."

What little growth there was in 1991 is attributed to the laundry detergent market, both in domestic and export shipments. The Department of Commerce estimates that exports of soaps and detergents in 1991 increased 25% to $487 million, and imports fell 4%. Increased automation is one factor that has given the U.S. industry a competitive edge in global markets.

As 1992 begins, raw material suppliers say they are really no better off than they were at this time last year. "Twelve months ago we were facing the threat of war in the Persian Gulf. Feedstock [prices] had skyrocketed, placing pressure on surfactant pricing. Twelve months later, the war has ended, we are in economic recession, and we are facing the same pressures we did one year ago. Feedstock prices are going up once again, placing pressure on surfactant pricing," says W. Jan B. Vogel, vice president for surfactants at Vista Chemical in Houston.

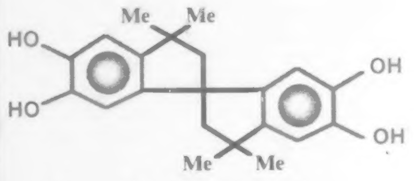
Du Pont's Fanandakis agrees: "I think that in general the recession has impacted businesses to the point of probably making it about equal to what it was in the prior year." For Carbide, however, Elling says business held up reasonably well in 1991. "The difference is that without the recession, we would be seeing substantial growth rather than just modest growth."

The forecast is slightly sunnier for 1992. In constant dollars, industry shipments are forecast to increase 3.7%, according to the Department of Commerce. In real terms, industry shipments are expected to increase from 2.5 to 3% per year well into the 1990s.

The companies that will fare best in 1992 are those that develop and market more environmentally safe, "greener-type" products that are somehow "revolutionary," says Fanandakis. He notes that Du Pont "is working on some next-generation-type products for soap and detergents that would fill the needs of current products." But he says the company, which supplies a number of specialty products such as perborates, potassium monopersulfate, and hydroxy acetic acid to the soap and detergent industry, is not yet ready to unveil these new offerings. And he declines to say whether they are targeted for the "more environmentally friendly" niche.

Indeed, soap and detergent producers are less concerned about getting their hands on lower cost raw materials than they are about securing materials that are environmentally sound. "The emphasis is not on 'give it to me cheaper,' but rather on supplying products that are environmentally safe and that perform certainly as well as if not better than competing products," says Fanandakis. "In fact, if you are supplying that need, in some cases, the customer is willing to pay more for an environmental product."

Although the need for improved, environmentally friendly products will be global in scale, some regions of the world are likely to require specific functional molecules to satisfy local



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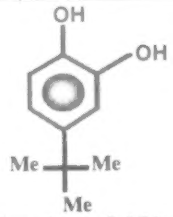

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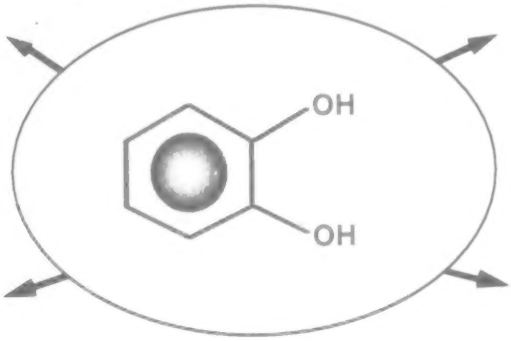

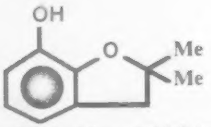

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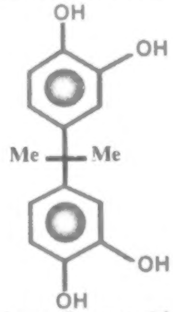

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needs. "Accordingly, BASF is putting added emphasis on utilizing its global resources to develop new raw materials and applications for the detergent industry that will meet increasingly stringent performance and environmental requirements," says Schoene.

Utilizing "world industry-segment teams," BASF is developing new products and application data aimed at meeting customer needs of the future, he says. "Research and development resources are being focused on new products and applications for surfactants and polymers. Combinations of Pluronic and Plurafac surfactants with Sokalan carboxylated polymers, for example, have been found to give soil-specific detergency advantages in laundry and hard surface cleaning formulations.

Schoene reports that U.S. production capacity for Sokalan homo- and copolymers, a multifunctional line of polycarboxylated dispersants for use in detergents and cleaning products, has been expanded in Spartanburg, S.C., to satisfy increasing customer needs in North America. Sokalan polymers can act as primary and secondary detergency boosters, processing aids, and powder detergent particle modifiers depending on polymer structure and molecular weight. These polymeric detergent additives also are being manufactured at multiple sites worldwide by BASF and will help facilitate the development of new detergent products, including multifunctional and highly concentrated formulations, Schoene adds.

BASF worker analyzes detergent formulation

Superconcentrates or concentrated detergents—which continue to be the biggest marketing trend in the soaps and detergents industry—are shining examples of the great potential of products marketed as environmentally stable and friendly. "Concentrated detergents address many of today's key issues including environmental awareness. Compact detergents use less packaging material and also eliminate some filler ingredients, so the impact on the environment is reduced. This appeals to consumers by enabling them to purchase environmental friendly products without sacrificing performance or convenience,"

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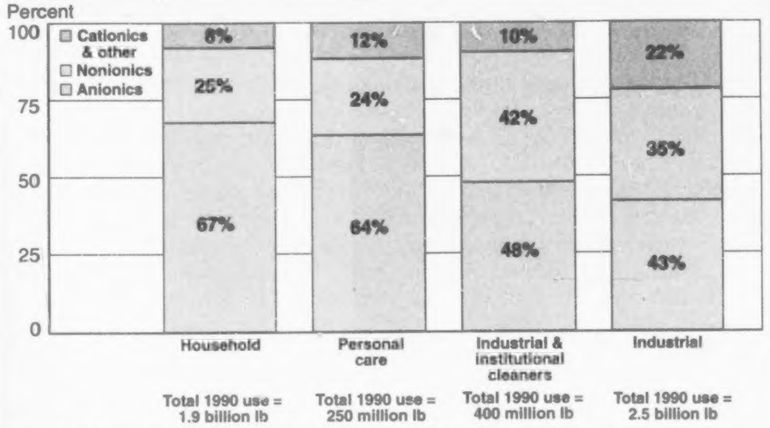
Household products are biggest user of anionic surfactants



Note: Excludes soap and oil field uses. **Source:** Colin A. Houston & Associates

explains Vista's Vogel. "We believe that concentrates will continue to be the trend in 1992," he says.

Compact detergents are a favorable trend for Vista. They "use the same major surfactants being used in conventional laundry powders and liquids in the U.S. today, which are linear alkyl benzene (LAB) and surfactant alcohol derivatives. Vista produces LAB, surfactant alcohols, and alcohol ethoxylates, so we will continue to supply these materials in concentrated detergents," adds Vogel.

In anticipation of the move toward concentrated liquid detergents, Vista has developed proprietary technology in the formulation of low-water concentrated laundry liquids that contain linear alkylbenzene sulfonates (LAS). "The most important property of this formulation is that it allows enzymes to remain remarkably stable without the use of added stabilizers."

In addition to the successful introduction of concentrated home laundry detergents throughout the U.S. during 1991, national and regional detergent manufacturers are now focused on work to add peroxygen bleach to their home laundry products, according to Frank E. Caropreso, FMC's detergent industry manager for peroxygens.

Another trend, related to automatic dishwashing detergents, is surfacing, but suppliers are mixed on how big a splash it will make. In the U.S. in 1991, the industry has shifted its focus for 1992 to commercializing liquid automatic dishwashing gels, says Peter P. Carfagno, detergents products technology manager at FMC's R&D labs in Princeton, N.J. Du Pont's Fanandakis says "I guess I don't see this as a revolutionary trend that one could equate to superconcentrates." Automatic dishwasher gels probably won't grow to be as big a trend as superconcentrates, certainly not in 1992, he says, "considering how long it took concentrates to get to where they are in the U.S. now."

But, to be sure, in the consumer market, gels are emerging as a significant new product. Gels offer improved dispensing advantages over the first-generation liquid dishwasher detergents, which are best described as slurries. The early liquids could separate and layer in the container. The gels contain more soluble ingredients, resulting in a more uniform and homogeneous product. These characteristics ensure easy dispensing from the container.

The key challenge in formulating gels is to achieve the desired solubility while balancing cost. To meet this hurdle, FMC developed improved phosphate materials through a balanced use of phosphate salts, according to Carfagno. The group worked with automatic dishwasher detergent formulators to improve the raw materials that would provide the cost and performance required.

"We have done a great deal of R&D in [automatic dishwasher] applications to develop improved materials, and our researchers know the technology of developing phosphate systems to formulate products exhibiting superior cost-performance characteristics," Carfagno adds. "The result is that the new [dishwasher] gels are unique in appearance; they are translucent. More importantly, they dispense beautifully with no sputtering. Sales and consumer acceptance of the new gels appears to be going well."

Companies are also at work to develop new surfactants. Ironically, although the recession and the increasing public concern for the environment are pinching companies involved in the soap and detergent industry, these two factors are also bolstering demand for certain surfactants. For example, more surfactants are needed to boost performance of products that lack builders such as phosphates, which are banned in many states.

In addition, more and different types of surfactants are required in formulating multifunctional products that consumers are demanding, according to a recent report by the Freedonia Group, a Cleveland-based consulting firm. These products combine fabric softeners, bleaches, enzymes, and antistatic agents into a single product, saving consumers money by shortening their cleaning products shopping list. However, multifunctional products frequently compromise properties such as cleaning and softening, when combined for consumer convenience. "Innovative surfactants, which are compatible with other ingredients, will provide opportunities for resourceful companies," the report says.

Increasing demand for nonirritating products, particularly shampoos and toiletries, but also household cleaners and light-duty hand dishwashing liquids, has spurred the development of gentler, yet effective surfactants. The increasing popularity of liquid personal soaps has also increased demand for synthetic surfactants, at the expense of natural soaps, adds the Freedonia report.

The increased consumer concern for reducing energy costs required for water heating has also led to changes in detergents. Lower wash temperature detergents require both more and different types of surfactants.

Given these trends, it's not surprising that surfactant shipments have outpaced the industry overall. They increased 5.9% to \$3.3 billion in 1991, or 4.2% in constant dollars, according to the Department of Commerce. Exports increased 3.2% to \$480 million, and imports increased to \$140 million, producing a positive trade balance of nearly \$341 million.

Still, the recession has forced manufacturers to keep a close watch on their costs to compete and protect their profit margins. And since raw materials are the most important cost behind soaps and detergents, they are the subject of the most scrutiny. Raw materials for soaps and detergents are derived from vegetable oil or animal fat or from petrochemical feedstocks. The raw materials are interchangeable and use is basically determined by cost of production, according to Vincent Kamenicky, an in-

Environmental concerns continue to erode phosphates market

The controversy over the use of phosphates in detergent products has been raging on for almost three decades now. In the 1990s, as environmental concerns become more and more important, the discussion of this issue will remain critical to environmentally conscious consumers and manufacturers.

Phosphates are used in some detergents as the sequestering builder that can inactivate hard water minerals (primarily calcium and magnesium) and hold them in solution. This increases the efficiency of the surfactant. In addition, phosphates furnish the necessary alkalinity for cleaning. They keep the dirt particles in suspension, helping prevent the particles from being redeposited on garments or dishes. In addition, they emulsify oily and greasy soils.

Phosphates are popular builders because of their effectiveness, reasonable cost, and safety for use with appliances, fabrics, and humans. They are nontoxic to aquatic life as well, says the Soap & Detergent Association (SDA).

The problem is that in combination with other nutrients like carbon, nitrogen, and potassium, for example, phosphates nourish algae and plant growth in lakes and streams. This process of fertilization, called eutrophication, occurs naturally but is speeded up as the population contributes waste to water. Lack of oxygen for fish is one of the consequences of the eutrophication of water.

Only about 25 to 30% of the phosphorus in wastewater comes from laundry detergents, with the remainder coming from human waste and food waste; and detergents contribute only 3% of the phosphorus annually entering U.S. surface waters, according to SDA. "Nevertheless, one way legislators have dealt with the localized problems of eutrophication is to ban or restrict the amount of phosphate in detergents," adds the association.

Although federal legislation aimed at banning or restricting phosphates in laundry detergents or automatic dishwasher detergents has been proposed, none has been enacted to date. All activity has been at the state and local level.

No state has banned phosphate use in automatic dishwashing detergents and where regulated the amount of phosphate allowed is generally no lower than 8.7%, according to SDA. In addition, in the past decade many ADD manufacturers have voluntarily cut the amount of phosphate (expressed as phosphorus) used in their products from a high of about 14 to 16% by weight to 8.7% or less today. Light-duty dishwashing liquids do not contain any builders, so no phosphates are present.

Phosphates used in laundry products have been more highly regulated. There are statewide bans in Georgia, Indiana, Maryland, Michigan, Minnesota, New York, North Carolina, Pennsylvania, Vermont, Virginia, and Wisconsin. In addition, bans are in force in some counties of Idaho, Montana, and Ohio; and in the municipalities of Chicago; Akron; Washington, D.C.; Portland, Ore.; Spokane, Wash.; and smaller communities in Illinois, New Hampshire, and Idaho. In addition, restrictions limiting the use of phosphate in laundry detergents to 8.7% and/or 7 g per use are in effect in Maine, Connecticut, and Florida. Further restrictive legislation is possible in the near future, since legislation has been introduced in several states.

In addition, many manufacturers have voluntarily pared down the phosphate content of most detergent formulations so that they contain no more than 8.7% phosphorus or 34% sodium tripolyphosphate (STPP), a principal builder that is still the standard of comparison for all other builders. [The exceptions are usually powder concentrates, which may contain up to 60% STPP (anhydrous basis) but are used in lower dosage levels in the washload. In fact, most laundry detergents containing STPP are designed to deliver 5.5 to 6.5 g of phosphorus per washload at recommended use levels.]

Indeed, these factors have put a crimp in U.S. demand for phosphates. In 1991, total estimated North American demand for all phosphorus-based products was expected to have exceeded 700,000 lb on a P_4 basis with exports remaining strong above the 140,000 lb level (P_4 basis), according to FMC. Total 1991 North American demand for STPP was slated to exceed 210,000 lb on a P_4 basis. Total exports of STPP for North America will exceed 40,000 lb on a P_4 basis.

Although the market for detergent phosphates is shrinking, it is still worthy of some investment. FMC, for example, has stepped up its participation in the market. Last spring, the company bought the phosphorus sales commitments of Occidental Chemical. In addition, the company continues to invest in R&D support for phosphates. For example, it is now installing new analytical technology at its Green River, Wyo., plant, which it claims is still the "the world's largest and lowest cost producer of STPP." The new technology will help "us to meet our customers' demands for higher levels of quality," says Peter P. Carfagno, FMC's detergents products technology manager.

Phosphorus is a core business for FMC, and the company continues to invest in both the Pocatello, Idaho, elemental phosphorus facility and the phosphate plants. FMC has also initiated improvement programs at the Carteret, N.J.; Lawrence, Kan.; Newark, Calif.; and Green River phosphate plants.

Capacity has substantially decline along with STPP demand in the home laundry market over the past 10 years and the exiting of the business by Olin and Occidental Chemical, according to Lesa Chittenden, marketing manager for cleaning compounds at FMC's phosphorus chemicals division.

From a domestic and worldwide standpoint, as STPP demand has declined, so has capacity. World STPP supply is shrinking, not only because of the exit of the two U.S. producers, but also because several producers around the world (in Japan, Europe, and South Africa) were expected to end production by year-end 1991. FMC says it does not predict significant reversal of this trend.

However, the rate at which product bans are being initiated has slowed, at least outside the U.S., says FMC. For example, in 1991 after consultation, the U.K. government announced that there should be no ban on phosphate use.

"The bottom line is that the number of worldwide phosphate producers and the amount produced will be declining over the next few years," says Daniel A. Corritore, export manager for FMC's phosphorus chemicals division. He expects phosphate supply and demand will be in balance over the next several years, given the additional capacity rationalizations and expected declines in demand. Worldwide production and consumption of STPP is about 2.5 million metric tons for 1991—the same as for 1990, he points out.

In 1992, FMC says it expects to see continued use of phosphates in home laundry detergents for the U.S. market. The export market for phosphates in home laundry detergents has also shown growth in Mexico and South America, says Chittenden.

However, the long-term outlook for phosphates and STPP is far from sunny. A recent SRI International report says that, "Although STPP's high performance characteristics have proved difficult to equal, its continued replacement appears likely, and it may totally disappear from U.S. laundry powders before the end of the century."

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dustry specialist at the Department of Commerce.

Both sources have their pitfalls. Pricing of basic petrochemical feedstocks, including ethylene, benzene, and *n*-paraffins, are tied to fluctuations in the crude oil market. Prices and supplies of natural fats and oils, particularly coconut and palm oils, are highly cyclical and subject to wide price swings. Generally, producers can reformulate using either the petrochemical-based feeds or the renewable ones; the two can be interchangeable.

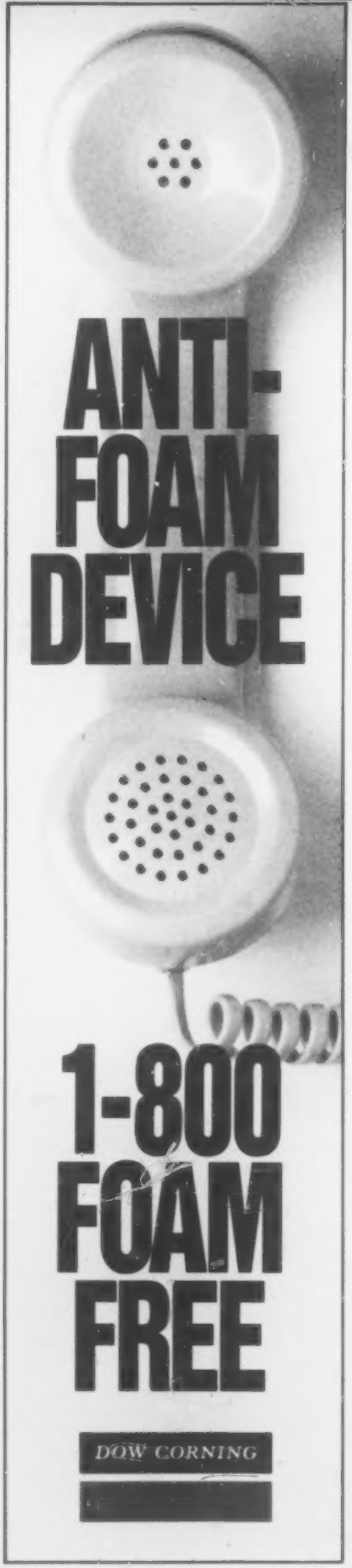
Many end users are taking a closer look at natural raw materials and products because they like the positive environmental message they present. "Natural soap production is taking hold and prospects are looking brighter," notes Kamenicky.

Like many in the industry, Chevron's Johnson says, "I don't see a performance difference between natural oils and synthetics." And producers of petrochemical-based feedstocks dispute that natural ingredients are better from an environmental standpoint. "It's more a perception than being more ecologically sound," he adds. But feeling these pressures, producers of petrochemical-based surfactant raw materials are scrambling to defend their offerings.

For example, Vista and Monsanto, the sole North American producers of LAB, which is sulfonated to produce LAS surfactants, teamed up recently to spread the word about their products' safety.

The two producers maintain that years of research and safe use confirm the environmental safety of LAS. It is one of the most widely tested detergent ingredients in use today, and has been examined under a variety of conditions to ensure that it has no significant effect on the environment, says Joseph C. Ledvina, director of environmental activities at Vista. Studies on LAS biodegradability show that it is rapidly and thoroughly degraded, and that it continues to degrade even in environments where oxygen is not present. These studies, coupled with real-world monitoring, confirm that LAS is not accumulating, despite increased use over the past three decades, and poses no threat to the environment, says James P. Mieure, product safety director at Monsanto.

LAS's highly effective cleaning properties and relative low cost have made it the most widely used surfactant for detergents worldwide, say the companies. It has also made it the subject of negative environmental claims by competitors. "As number one in its field, LAS is a target everyone else is shooting at to move into the same market," says Ledvina. "Green marketing is an angle our competitors are using now, and we don't want it to be forgotten that LAS is the original green product used to replace branched alkyl benzene (BAB), which was slow to degrade and caused a lot of visual and toxic problems."



CIRCLE 13 ON READER SERVICE CARD

A summary of 1991 phosphate actions

■ CONNECTICUT
The Department of Environmental Protection testified at a March 1 hearing that it already had sufficient regulatory authority over water quality and did not need a bill that would amend the state's detergent law to ban the sale of all phosphate detergents. No action occurred on this bill.

■ LOUISIANA
No hearings were held on a bill introduced last spring that would empower the Department of Environmental Quality to regulate the phosphate content of "cleaning agents."

■ MASSACHUSETTS
Passed by the state Senate last spring, S. 50 was amended on the House floor in September and recommitted to the House Commerce & Labor Committee, where it currently resides. The bill would ban the use of phosphate in household laundry products, require regulatory review and approval for industrial and institutional exemptions, and impose broad ingredient reporting requirements on manufacturers of household cleansing products.

■ MONROE COUNTY, FLORIDA
In July, the Monroe County Commission approved phosphate ban amendments negotiated between the Soap & Detergent Association and the county attorney's office. The amended ordinance exempted from the county's phosphate ban all household and industrial and institutional automatic dishwasher products with a phosphorus measure of 1.1 g per tablespoon or less. It also provided for the continued use of all industiral dishwasher products for three months beyond the Oct. 19 effective date so as to allow for performance evaluation of lower phosphate products in such applications.

■ OREGON
This past summer the governor signed legislation limiting the use of phosphate in laundry detergents to 0.5% phosphorus by weight, and in automatic dishwasher detergents to 8.7% by weight, effective July 1, 1992. Industrial and institutional applications are exempt.

■ SOUTH CAROLINA
A phosphate ban bill passed by the legislature and signed by the governor in late May restricts phosphorus use in household laundry detergents to 0.5%, limits the automatic dishwasher detergent maximum to 8.7%, and provides for the traditional industrial and institutional exemptions, including commercial laundries.

■ TEXAS
In May, the city of Austin adopted an ordinance banning the use of phosphate in home laundry detergents with exemptions for automatic dishwashing and industrial and institutional products. Effective date is August 1992. Since then, La Grange, Smithville, and Wharton have adopted similar phosphate bans modeled after the Austin ordinance. All three become effective in fall 1992.

■ WASHINGTON
A phosphate ban bill died in committee last spring owing to lack of any scientific evidence that it would improve water quality.

■ FEDERAL
The Lakes Assessment & Protection Act of 1991, sponsored by Sen. George J. Mitchell (D.-Me.) would require the Environmental Protection Agency to establish a five-year phaseout of the use of phosphates in detergents. Introduced in May, the bill has not received priority attention.

Vogel explains, "Vista's history of manufacturing environmentally friendly surfactant raw materials dates back over 25 years. Vista was first to develop and commercialize linear detergent alkalate and linear synthetic Ziegler alcohols. Our linear detergent alkylate was used to replace 'hard' alkylate. Similarly, less biodegradable, nonionic surfactants were replaced with biodegradable surfactants based on linear alcohols. These environmentally friendly products are still widely used today."

In another move to defend the environmental profile of a product, a group of companies including Texaco Chemical and Union Carbide teamed up to do a study to demonstrate the environmental quality of alkylphenol ethoxylates, raw materials used in making laundry products and cleaners. The study, done in coordination with the Environmental Protection Agency, in-

C&EN staff photo

Gel formulations are improving automatic dishwasher detergents

volved 30 rivers and "found that these products are not building up in the environment. So people with environmental concerns about using them need no longer have these concerns," says Carbide's Elling. At the annual Soap & Detergent Association (SDA) meeting early next week, Carter G. Naylor of Texaco Chemical is slated to present the findings of the study in a paper entitled, "Alkylphenol Ethoxylates in the Environment."

Despite these concerns, Kamenicky expects to see growth in both synthetic and natural surfactant products in the near future. And, indeed, some of that growth in each sector will come from changes made to meet consumer demand for more environmentally friendly products. Reformulation, including the incorporation of biodegradable raw materials, will account for some synthetic growth, he says.

In 1992, the value of industry surfactant shipments is forecast to increase 5.1% in real terms, he estimates. Exports and imports are expected to increase as global concentration leads to fewer companies. Exports to developing countries will continue to grow, and imports from Western Europe also will post gains, adds Kamenicky. "The industry will continue to be affected by acquisitions and mergers. Environmental issues and concerns will dominate production with growth rates of 5 to 5.5% per year over the next five years," he adds.

Vista is one chemical company that remains "optimistic" about the prospects for 1992. Vogel reports the company has been experiencing "a continued increase in demand for all our products from many different market segments. We are anticipating another good year in LAB sales. In alcohol and derivatives, we anticipate ethoxylate sales for Vista in 1992 will outperform 1991."

In the first of several steps that it is taking toward meeting increased customer demand, Vista recently completed the debottlenecking of the ethoxylation unit at its alcohol plant in Lake Charles, La. Capacity was increased from 65 million to 80 million lb per

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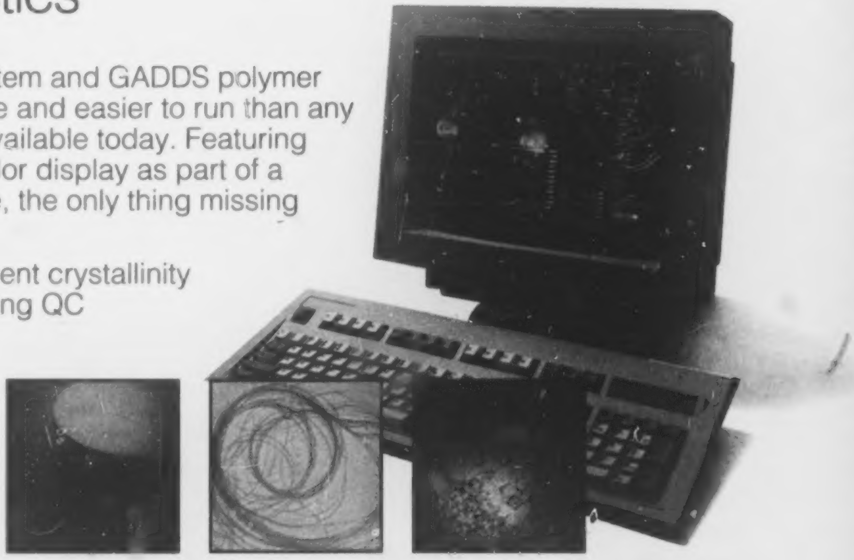

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year. In addition, says Vogel, "we are evaluating investment in LAB and alcohol capacity on a worldwide basis."

The inventory requirements for the rollout of new compact brands in 1992 will help Vista's sales, he anticipates. "And the improving economies of Latin America are also expected to provide a boost to our export business," says Vogel.

Chevron's Johnson is also sanguine about what 1992 holds for the α-olefins business as it relates to soap and detergent raw materials. "Rising ethylene prices is one factor that could really hurt those companies supplying petrochemical based feedstocks, by making way for natural oils," says Johnson. Chevron makes the key feedstocks used in the production of α-olefin sulfonates and fatty amine oxides. But that price rise does not seem to be in the cards. "It would take an unforeseen, unlikely disruption of crude oil or ethylene to raise prices to that level, and I don't see that scenario in 1992. I don't think pricing will have negative impact on demand" of petrochemical-based feedstocks in 1992, Johnson points out.

α-Olefin "volumes have gone up considerably" over the past 12 months, adds Johnson, "particularly noticeably in the first half of the year." He adds that the soap and detergent business is "more seasonal than one would expect" in a business that sells its products year-round. Business was slower "through the second half."

Johnson reports that Chevron's α-olefins sales were up 40% in 1991 from 1990, noting "strong customer demand." The increase in sales volume also reflects the additional output from its 250 million lb-per-year normal α-olefins unit, which went on stream at the Cedar Bayou plant in Baytown, Tex., in May 1990. (The unit was idled five months after its startup by a fire, but was restarted in March 1991.) And Johnson is "anticipating a strong first half again. We don't see any falloff, rather we anticipate an increase in demand in 1992."

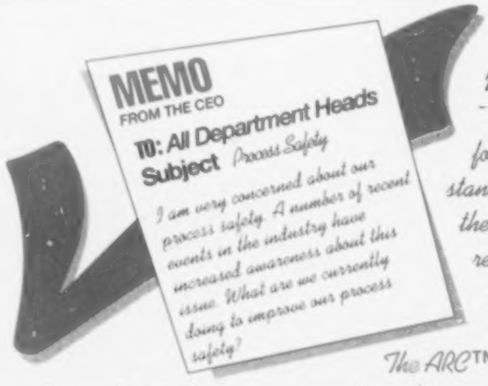
Aiming to better meet its customers' needs, Chevron is proving out a new, lower paraffin technology for its α-olefins production, says C. Eric Spore, a product specialist in Chevron Chemical's olefins and derivatives division. The new technology, which likely will be commercialized this month, will produce a purer α-olefin product for its customers, including those in the soap and detergents business.

For its part, FMC has been working on a new technology to help soap makers cut raw material costs in the midst of the recession. Last February, the company was awarded a patent for a new detergent manufacturing technology using soda ash and surfactants. Ba-

Eight U.S. companies produce surfactants, raw materials

	Surfactant raw materials			
	Linear alkylbenzene	Detergent alcohols	Ethylene oxide	Surfactants
Hoechst Celanese			■	Alcohol ethoxylates
Monsanto	■			Alkylphenol ethoxylates
Procter & Gamble		■		Linear alkylbenzene sulfonates, alcohol sulfates, alcohol ether sulfates, alcohol glyceryl ether sulfonates, fatty amine oxides, fatty alkanolamides
Shell Chemical		■	■	Alcohol ethoxylates
Sherex Chemical		■		Fatty alkanolamides, fatty amine oxides, alcohol ethoxylates
Texaco Chemical		■[a]	■	Alcohol ethoxylates, alkylphenol ethoxylates
Union Carbide			■	Alkylphenol ethoxylates
Vista Chemical	■	■		Linear alkylbenzene sulfonates, alcohol ethoxylates, alcohol ether sulfates

Note: 1990 data; some surfactants may be used captively only and some companies offer additional surfactants produced through toll arrangements. **a** Although Texaco has no detergent alcohol capacity, it obtains its alcohols from Ethyl Corp. through a long-term arrangement. **Source:** SRI International's 1992 Chemical Economics Handbook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sically, the process will allow manufacturers to neutralize surfactant acids with soda ash, resulting in cost savings when compared with the purchase of surfactants already neutralized. The new process technology helps manufacturers develop dry, free-flowing granular detergents, according to FMC's Carfagno. "As the trend toward compacted detergents grows, the industry is increasingly interested in higher density detergents that are more weight-to-volume efficient; this often means non-spray-dried detergent manufacturing technology," he explains.

The company has already licensed the process to one "major soap and detergent" manufacturer that it declines to name and is now offering it to other companies, according to Michael J. Ruffini, soda ash product manager for detergents at FMC. "Soda ash is becoming a more important raw material in home laundry detergent formulations because the chemical is one of the lowest cost, effective ingredients," adds Ruffini.

Carbide is clearly upbeat about its future in the surfactants business. Elling expects that the total market for surfactants will not change much in 1992, but that there will be plenty of replacements among types of surfactants. Carbide, he anticipates, will be on the displacing side of that trend. "We will have some new product offerings in 1992 that will increase our market share," says Elling. Although he says Carbide is not ready to unveil those products, he adds that they are ones that "we believe are better [than others currently available] at competitive cost."

Besides its November 1990 purchase of Rohm & Haas' Triton surfactants and alkylphenol business, last September the company also unveiled plans to build a specialty surfactant plant at its South Charleston, W.Va., chemicals complex. The 50 million lb-per-year plant, slated for completion by mid-1993, will be capable of producing the full range of Triton brand specialty surfactants. Currently, Rohm & Haas is producing the surfactants for Carbide at its Philadelphia plant.

Marking another major investment in surfactant capacity, American Cyanamid plans to expand and modernize its Warners, N.J., sulfosuccinate surfactant operation by the fourth quarter of this year. The move will increase Cyanamid's Aerosol brand surfactant capacity by about 10 million lb. Cyanamid's Aerosol, Aerodri, Deceresol, Complemix, and Solusol sulfosuccinate, sulfosuccinamate, and docusate surfactants are used in a broad range of applications, such as general-purpose cleaners, cosmetics, emulsion polymerization, textile finishing, mineral ore processing, food additives, pharmaceuticals, plastics, paints, inks, coatings, and agricultural products. The economy of scale and equipment versatility afforded by the expansion will enhance Cyanamid's surfactant production as well as improve its custom manufacturing and tolling capabilities, says the company. The new capacity will also help Cyanamid expand its surfactant presence through product line extensions, new product introductions, and strategic alliances.

Sherex, which manufactures a range of over 100 products from natural fats and oils, is also enthusiastic about 1992. There's been a lot of movement in the household cleaning area over the past year with companies including Clorox and Procter & Gamble introducing new products, says Pamela D. Shisler, industry manager for household and industrial surfactants at Sherex Chemical. Their competitors "will need their own entries," so she expects that in 1992, the household cleaners market will remain dynamic with new products creating "new opportunities for specialty surfactants."

Those are among the opportunities that the company is hoping to turn into market share. "We have a smaller percentage of the market, so we have a lot more potential to grow. We expect to perform better in 1992 as the trend toward specialties begins to snowball."

Just how well Sherex and other specialty surfactant makers fare in 1992 will have something to do with how feedstock prices behave. Coconut oil prices, which rose during the summer, are still high, keeping the industry

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wondering when they will drop again. Shisler adds: "They've got to come down sometime."

Specialty feedstocks are generally more expensive than the commodity feedstocks they can replace, she explains, but the overall cost can end up the same because a customer may use less of the specialty replacement, which is often more environmentally friendly. "So a customer gets a bigger bang for the buck."

While the industry reformulates with different surfactants, it also continues to struggle to come up with acceptable substitutes for phosphates in their use as builders. Phosphates are indisputably the most efficacious builders for use in heavy-duty laundry detergents and automatic dishwasher detergents, but more than a decade of negative publicity and burgeoning state legislation have brought about a decline in their use in detergents.

Recent technology has provided improved phosphate-free laundry products. For example, liquid laundry detergents, which contain no phosphate, now have half of the market in some areas, according to SDA. This has been achieved using a number of alternative builders including zeolites, sodium citrate, sodium carbonate, and sodium nitrilotriacetate.

The banning of phosphates in laundry detergents continues to contribute to a number of reformulation changes in the industry. For one, phosphate regulations have contributed to growth in laundry liquids, most of which do not contain builders. It has also boosted demand for surfactants because more of them are needed to achieve acceptable performance from unbuilt products, according to a report on surfactants, household detergents, and their raw materials released this month by SRI International.

An even bigger challenge is dealing with the phosphates' crucial role in automatic dishwasher detergents. The industry has found no way to replace phosphates in critical cleaning operations such as automatic machine dishwashing in homes, restaurants, and institutions and the cleaning-in-place of food and beverage equipment such as in dairies, says SDA. A veritable substitute must not only be effective at reasonable cost, it must also be safe for home use, safe to crawling infants who can get detergent out of dishwashing

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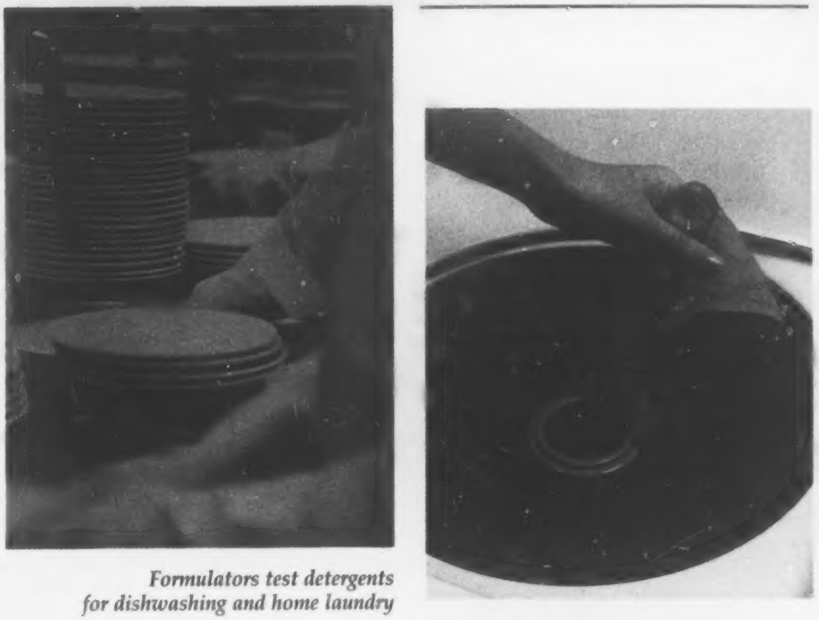


Vista Chemical photo

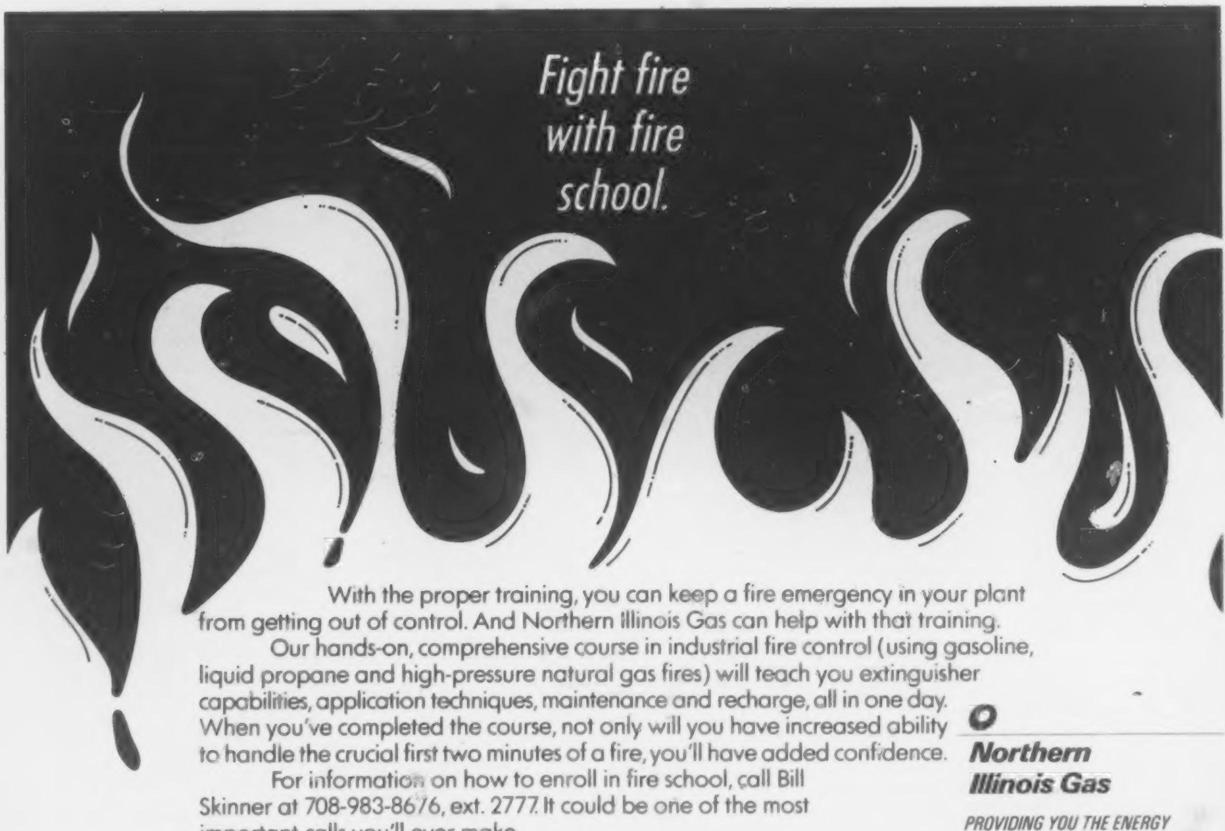
Formulators test detergents for dishwashing and home laundry

dispensers, and safe for the environment. Current research is focusing on organic builders, polymers, enzymes, and oxygen bleaching systems, according to SDA.

As soap and detergent formulators look for builders that have a better environmental quality profile, they are also investigating the use of more environmentally friendly peroxygen chemicals across the board in home laundry detergents, liquid all-purpose bleaches, automatic dishwashing detergents, consumer multipurpose cleaners, and industrial and institutional products.

With the successful U.S. introduction of concentrated home laundry detergents almost behind them, national and regional detergent manufacturers are now focused on work to add peroxygen bleach to more of their home laundry products. A number of detergent products such as Tide with Bleach are already on the shelves, and the market is clearly headed in that direction. When concentrates have fully penetrated the market, soap and detergent manufacturers will more heavily promote this new product benefit, sources say.

Activity is also accelerating to further develop and market hydrogen peroxide as a separate liquid bleach product that is added directly to the washload. The trend to use of peroxide-based bleaches continues to grow because peroxide, "an environmentally safe chemical, provides excellent cleaning performance without color or fabric damage," according to FMC's Caropreso.



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Cost-effective, environmentally friendly products challenge raw materials supplies

The market for industrial and institutional cleaners, the largest market for surfactants, had a weak year in 1991. What's more, it will probably remain "slow as long as the recession" continues to plague restaurants and hotels, for example, notes Pamela D. Shisler, industry manager for household and industrial surfactants at Sherex Chemical. Fewer patrons mean a decreased need for cleaners and disinfectants.

Despite suffering demand, the recession has put increasing pressure on soap and detergent manufacturers to provide cost-effective products. And environmentally conscious manufacturers and consumers also want products that have minimal environmental, safety, and health effects. These challenges could spell opportunities for raw materials producers that can come up with products to meet these growing demands.

"I think there are definite environmental issues that to a degree are affecting industrial detergents and processes," says George Elling, market development manager for Union Carbide's surfactants business. For example, he adds, "people in industry have to be more and more concerned about effluent from plants, considering that the waste treatment authorities at the state, local, and federal levels will not allow them to have anything but almost pure water in their waste streams. This means that people have to look at the chemicals and processes they are using so as to keep virtually any organic, heavy metal, or environmentally unfriendly product from leaving the plant." If a company is using a surfactant that is very difficult to treat in a water treatment plant, and the local water authority can't process it, the company will have to reformulate. Developing and marketing surfactants for this reformulation process opens up potential markets for surfactant producers, he adds.

In the past few years, there has also been an increasing emphasis on sanitation, probably because of greater public awareness of health concerns, says Marilyn Bradshaw, a business manager at Colin A. Houston & Associates, which recently published a study, "Industrial Applications of Surfactants-North American Forecast to 2000." This could spell growth for disinfectants and sanitizers.

Another issue affecting industrial and institutional markets is the decreased language skills of the work force, she notes. "Many employees who use the cleaning products are either barely literate or do not speak or read English. In order to ensure safety and economy, products must be very easy to use, and premeasured or automatic dosing is preferred," says Bradshaw.

FMC's Peter P. Carfagno, detergent products technology manager, agrees. "In the industrial and institutional area, there is continued interest among formulators to develop novel product forms that will provide automated, metered delivery of detergents for [automatic dishwashers] and other cleaning compounds. These provide benefits in performance, cost savings through more efficient use, and enhanced worker safety through minimum exposure."

The demand for safer industrial and institutional formulations may also open up a new market niche for surfactant suppliers. Traditionally, the industrial sector has relied more heavily upon synthetics, such as aromatics and other petrochemicals, than the household and personal care sectors. The household and personal care sectors are more heavily dependent upon natural fats and oils, because mildness and low irritation qualities are required for skin contact applications. But that is changing. Alkaline cleaners, although remaining the leading segment of industrial and institutional cleaners, "will face increasing supplantation by specialty cleaners and safer synthetic cleaners," notes a recent surfactant study by the Freedonia Group, Cleveland.

Energy conservation and improved cost and performance continue to be important in this market, Bradshaw says. Wash temperatures are lower and use of liquid products is growing at the rate of 8% per year at the expense of dry products. That's because liquids can be easily and accurately injected in measured doses into closed systems. In addition, they require no heat for dissolving and all components are immediately available in solution, which is important in low-temperature cleaning. Liquids also eliminate the handling problems caused by dust in dry detergents.

Powders are also declining in the commercial dishwashing products category—in part because of preference for liquids and slurries, but mostly because of the increasing popularity of Ecolab's encapsulated solid-product system, which automatically dispenses concentrated dishwashing detergent, notes Bradshaw.

However, there are some exceptions to the trend toward liquids. In the hard surface cleaners category, for example, the trend from powders to liquids has leveled off and may even be reversing slightly because of environmental concerns about plastic packaging of liquids, Bradshaw says.

Packaging has been an important area of change in recent years, she says. Many large-volume products are being packaged in a "bag-in-a-box" form rather than the 5-gal pails and the 55-gal drums that were common in the past. The 55-gal drums are difficult to move and make disposal a problem. The new packaging forms are less bulky, less costly, and more environmentally sound. For these same reasons, bulk delivery of large-volume products is becoming more and more common.

"The focus on peroxygens for use in consumer cleaning compounds is widespread, and we expect to see peroxygens formulated into multifunctional cleaners and automatic dishwashing products as well as [their] continued use in liquid bleaches and home laundry products," adds Caropreso.

Du Pont's Fanandakis notes that peroxygens are displacing chlorine in most of these uses. "In [automatic dishwashing detergents], for instance, chlorine is already pretty much displaced in the European market," he says. "And that will probably happen in the U.S., too, in the next year or so."

In the industrial and institutional area, researchers are looking at developing a formulation of hydrogen peroxide and peracetic acid to be used as a sanitizer for cleaning applications in food and beverage processing plants, notes Caropreso. John Parker, marketing manager for persalts at Interox America, says he sees "major interest in this market area," in which Interox is a "very significant" player in both Europe and the U.S.

Recognizing the potential for growth in demand for peroxygens, both Du Pont and Interox America moved forward in 1991 with capacity investments. In December, Interox America started up a new plant in Deer Park, Tex., to produce sodium perborate monohydrate, a solid peroxygen bleaching chemical used in heavy-duty detergent powders and bleach additive products. The facility has an initial capacity of 45 million lb per year of monohydrate in detergent powders and was designed for future expansion to enable Interox America to keep pace with a rapidly growing market.

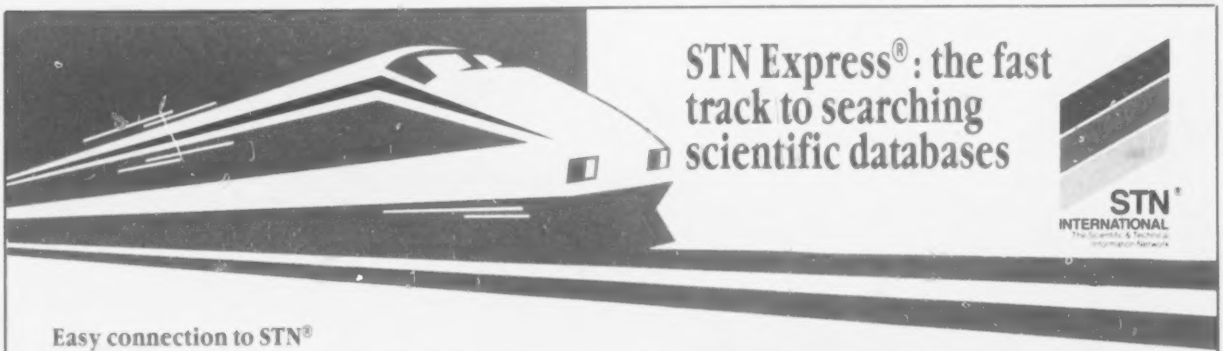
Du Pont became the first North American producer of sodium perborate monohydrate last year with its unit at Memphis, Tenn. Rather than build a new plant, the company dedicated a portion of its perborate tetrahydrate capacity to supply over 30 million lb per year of monohydrate. Du Pont says this is the first phase of adding monohydrate capacity to meet a growing demand in North America and the rest of the world. As demand increases, Du Pont claims it will also be "in an excellent position to expand our capacity," says Fanandakis.

According to Parker, worldwide demand for this product has doubled between 1987 and 1989 "and further substantial growth is predicted." In five years the potential North American market for monohydrate is estimated at 60 million to 80 million lb per year, says Fanandakis.

In Europe, the monohydrate variety is replacing perborate tetrahydrate in concentrated powders. Meanwhile, in North America and Japan, the introduction of new technology has opened up new demand for monohydrate. Basically, sodium perborate monohydrate is preferred over tetrahydrate because it dissolves faster and gives better stability for low- or no-phosphate detergent formulas.

To meet the changing needs of the soap and detergent industry, companies are also developing a host of other additives and products that provide more than one function and do so at reduced cost. For example, besides marketing its soda ash for use in neutralizing surfactants, FMC is also pushing it as a builder, an agglomerating agent, a surfactant carrier, and as an alkaline source in detergents. "Soapers need maximum performance, and that is why soda ash is becoming a more important raw material. Of all the active ingredients in home laundry detergents, soda ash is one of the lowest cost, most effective raw materials," says Ruffini.

Meanwhile, Dow Chemical is boosting worldwide capacity for its Dowanol glycol ethers, which act as surfactants and coupling agents in household and industrial hard surface cleaners, floor waxes, carpet cleaners, metal cleaners, disinfectants, and germicides. Cleaners make up the second largest end-use market for glycol ethers after paints and coatings. Dow is currently in the process of expanding its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Stade, Germany, glycol ether facility. The expansion, which will be completed in 1992, will increase Dow's total glycol ether capacity to 485 million lb per year. The company has two U.S. manufacturing locations—Midland, Mich., and Plaquemine, La. Dow also manufactures glycol ethers in Terneuzen, the Netherlands, and San Lorenzo, Argentina.

It is increasingly important for U.S.-based raw materials suppliers and soap makers to remain active both domestically and globally. Markets in the U.S., Western Europe, Japan, and East Asia are all estimated to be about the same size, according to the Department of Commerce report. Sociodemographic trends will play a major role in future international development. Population has stopped growing in Europe and Japan, where the average age of consumers is increasing and households are getting smaller. Climate and types of washing machines will also be factors in determining the industry's global marketing efforts, says the report.

Both industrialized and developing countries have the potential to provide significant market growth, the report adds. There is a close correlation between a country's consumption of soaps and detergents and its standard of living. The industry's frequent introductions of new products reflect improved technology and ever-changing consumer preferences.

Events in Eastern Europe and the republics of the former Soviet Union will present challenges and opportunities, starting with additional exports and leading later to enhanced investment opportunities as these countries move to market economies.

"Economies in transition may present the biggest opportunity in this decade," the Commerce report says. "With investment dollars limited, U.S. companies face difficult choices. But they will need to move quickly because international competition will be keen. Although overcoming trade and investment obstacles will take time, Eastern Europe appears to offer attractive opportunities for exports—at least until the private sector builds production capacity. Domestic demand, geography, cost of fuel and feedstock, and a ready labor force may make the Eastern European countries an ideal location for world-scale plants with sufficient capacity to eventually export to Western Europe and Asia."

When it comes to opportunities in Eastern Europe, Chevron Chemical is one raw material supplier that has its foot in the door. In 1987, the company licensed its technology to the Czechoslovakian government. Under the deal, Chevron will be able to obtain surplus product from the country's new 265 million lb α-olefins plant when it becomes operational in June or July of this year. Chevron has been helping with the startup of the plant. For example, last fall it helped to train 26 Czech plant operators at its U.S. α-olefin facilities.

The Czechs will supply Eastern Europe with the new plant and Chevron will be free to sell whatever the Czechs cannot to Western Europe. Detergent alcohols are likely to be low on the list of what Chevron can tap from the Czech plant. "The detergent alcohol fractions are spoken for. Obviously, they have established a home for these products in those countries," says Johnson. Given that "we and other suppliers have not been supplying detergent alcohols over there," they probably were not used before in those countries. Thus he wonders if Eastern Europe is now in the process of converting away from branched alkyl benzene, which has been the old standby there for many years.

Given the importance of international markets to soap and detergent raw materials suppliers, it's not surprising that many of them are working toward the goal of International Standards Organization (ISO) certification. Du Pont expects that its Memphis solid peroxygens facility, which includes the perborate as well as potassium monopersulfate units, will be ISO 9000 certified by the first half of 1992. "The [change in the] European Community this year is part of what is driving us toward that goal," says Fanandakis. "We are a global supplier; we service all markets and we do export some of our [detergent-related] products."

Chevron Chemical, which does a big export business in α-olefins, detergent alcohols, and other soap and detergent feedstocks, is working on its ISO 9000 certification, aiming to meet that goal by August of this year. "Our customers in the detergent business want this," says Johnson, "but everyone in the chemical industry is marching in harmony toward these goals." ☐

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PRELIMINARY PROGRAM – ACS NATIONAL MEETING IN SAN FRANCISCO PAGE 41

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CHEMICAL & ENGINEERING NEWS

C&EN

JANUARY 27, 1992

NEWS OF THE WEEK

- U.S. and China conclude pact to improve intellectual property protection in China, a move expected to benefit U.S. pharmaceutical and pesticide industries. **Page 4**
- U.S. chemical industry expresses support, with some reservations, for proposed global trade rules, but puts priority on outcome of market access negotiations. **Page 5**
- NASA launches space shuttle *Discovery* carrying microgravity lab and international seven-member crew, which will study effects of microgravity on various materials and life forms. **Page 5**
- Vaccine based on envelope glycoprotein of simian immunodeficiency virus protects monkeys against SIV infection, raising hopes that vaccine can be developed against AIDS virus. Page 6
- FDA advisory panel recommends approval for marketing of Chiron's interleukin-2 to treat kidney cancer. Page 6

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BUSINESS

Chemical industry in newly independent Soviet republics, now undergoing extensive reorganization, presents formidable challenge for western firms seeking to do business there. **Page 19**

Attracted by growing European demand for titanium dioxide, Du Pont plans to produce the pigment there, either by buying land and building or via acquisition. **Page 22**

Demand for synthetic rubber will recover this year and grow at annual rate of about 2% through 1996, according to the International Institute of Synthetic Rubber Producers. **Page 23**

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Pharmaceutical firms are upbeat about reform in FDA procedures that could cut review times for new drugs, attune U.S. and foreign regulation. **Page 28**

Impact on industry of unauthorized use of intellectual property is probed at National Research Council meeting. **Page 29**

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Gas-phase studies of oxidative addition of alkanes to organometallic complexes shed light on mechanism of action. **Page 32**

Antibody raised against nonchiral hapten catalyzes stereospecific reduction in presence of common reductant. **Page 33**

China's Top 10 science achievements in 1991 are compiled from its government newspaper's first annual survey. **Page 34**

PRELIMINARY PROGRAM

ACS's 203rd national meeting in San Francisco in April offers variety of symposia; listing and highlights of symposia and full general program are included. **Page 41**

NEWS FOCUS

Canada's chemical industry supports a North American Free Trade Agreement with the U.S. and Mexico, though it is more concerned with protecting its marketing turf in the U.S. than with going after a small market in Mexico. Page 9

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Thermophilic bacteria

I was interested to note the letter from Richard Henderson (C&EN, Dec. 23, 1991, page 3) concerning thermophilic bacteria. The role of thermophiles was well known when I entered the canning industry in 1931. They cause insidious flat sour spoilage in canned foods. "Flat," because the can ends are not distended as in other types of spoilage and cannot be separated by external appearance. The soured product is unpleasant to taste, but not toxic.

The thermophiles are very heat resistant and not destroyed by conventional thermal processes. The problem can be avoided by maintaining warehouse temperatures substantially below 120 °F. Thermophilic bacteria are defined in my 1913 Funk and Wagnalls dictionary.

John M. Jackson
Lakeside, Mich.

Ethics in interviews

I sympathize wholeheartedly with Bhajendra N. Barman (C&EN, Jan. 6, page 4) and Molly Gleiser (C&EN, Nov. 4, 1991, page 4) in their complaints about the abuses from interviewers. Their cases were particularly outrageous in light of the current depressed market for hiring in the chemical industry. However, it might be of some interest to the reader to go back to a gentler and kinder time.

In the early 1960s, when I was working for a large chemical company in the Washington, D.C., area, we were trying to recruit a staff in as brief a time as possible for a new research laboratory. One promising graduate student from the West Coast and within a few months of receiving his degree solicited an interview with us and we were only too willing to accommodate him. All expenses were paid both for his trip east and for the best accommodations in the Washington area. After he had completed his day of interviewing, I was assigned to him as his host, and we ate at a restaurant selected by him. During dinner he confided in me that he had no intention of taking the position, and the only reason that he had requested an interview was to obtain a free trip to the East Coast to see his parents—his father in particular.

Without a trace of guilt, he then informed me that his father was an executive vice president in New York City at one of the five largest chemical companies in the country. Needless to say, sitting on the other side of the interviewing process, I was shocked by the unethical treatment from this "potential" employee of our company. Without remembering names, I would not be surprised if the same individual 30 years later is not now screening candidates in the egregious manner described by both Barman and Gleiser. Based on their experiences, a course in ethics should be a requirement not only for the individual chemist but also for all interviewers.

Nelson Marans
Silver Spring, Md.

Supercritical water

As one of the inventors of the supercritical water oxidation (SCWO) process, I am both pleased and concerned by your special report [by Robert W. Shaw et al.] on supercritical water (C&EN, Dec. 23, 1991, page 26): pleased to see the attention that the field is receiving; concerned about the misconceptions that the article appears to have created.

I received a call today from a *Wall Street Journal* reporter who wanted to know how anyone in his right mind would consider doing anything practical in a medium that dissolves gold. The fact is that most of the fascinating (and very expensive) research cited in your article has very little to do with the SCWO process that we at Modell Development Corp. (MODEC) have developed for treating wastes. Our SCWO process is conducted at 500 to 600 °C and 250 bar, where the density of water is less than 0.1 g per cc, the dielectric constant less than 2, salts (and gold) are insoluble, and "molecular charisma" is not to be found. Under these conditions, water is so electrochemically inert that corrosion is far less severe than in hot liquid water at 200 to 300 °C. These conditions are so far removed from the critical point that the thermodynamic behavior of binary mixtures of water and sodium chloride can be modeled by a simplistic Redlich-Kwong equation of state.

MODEC's SCWO process is capable of ultrahigh destruction efficiencies in a stackless system where gaseous effluent is condensed as collected as liquid carbon dioxide. Over the past two years, we've solved the salt clogging problem, demonstrated operation of a bench-scale prototype through 120-hour round-the-clock tests, and completed process design and

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Canadian Chemical Industry Backs North American Free Trade Pact

But companies believe it's better to protect existing market opportunities in large U.S. market than to increase small Mexican market

Earl V. Anderson, C&EN Northeast News Bureau

In June 1990, the presidents of Mexico and the U.S. agreed to negotiate a bilateral trade pact between the two countries. In September 1990, Canada announced that it would join in the negotiations, transforming the trade talks into a springboard for a possible trilateral North American Free Trade Agreement (NAFTA). The negotiations still are going on.

Earlier, C&EN examined NAFTA from the Mexican chemical industry point of view (C&EN, Sept. 9, 1991, page 7). In this second of a series of articles, C&EN takes a look at how the Canadian chemical industry feels about NAFTA. A future article will examine NAFTA through the eyes of the U.S. chemical industry.

G. Firman Bentley, senior vice president of Nova Corp. of Alberta until his retirement recently, says that Canada's interest in NAFTA is both "offensive" and "defensive." Many leaders in the Canadian chemical industry express those same sentiments.

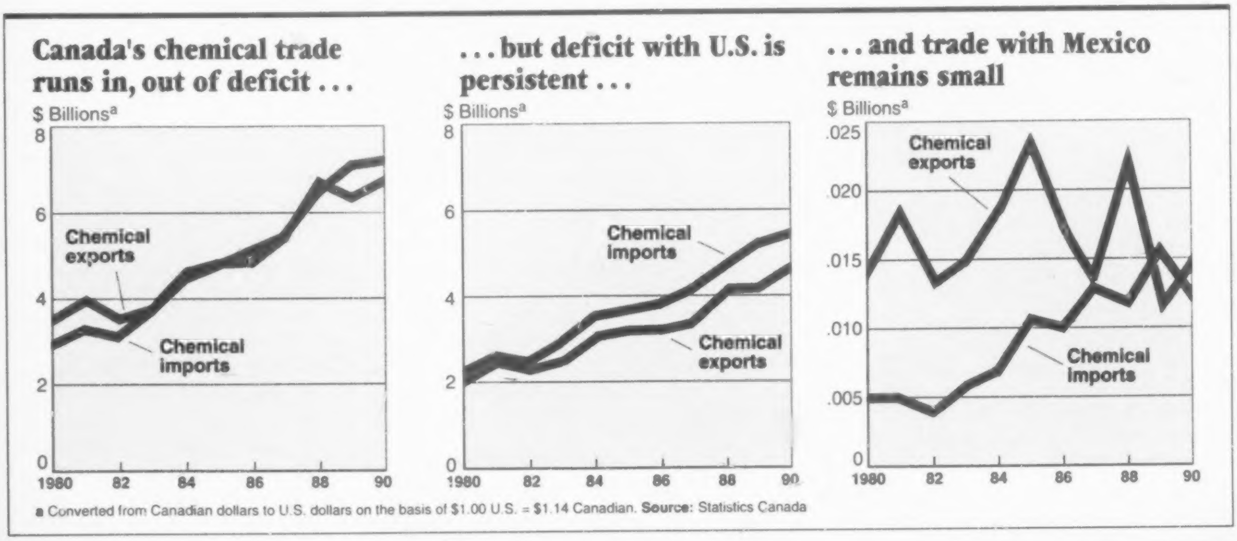
Last year, Canada sold $15 million worth of chemicals to Mexico. That's a minuscule 0.2% of its total chemical exports. Even the best offensive weapons that Canadian chemical producers can possibly hope may come out of the NAFTA negotiations will not raise those numbers significantly in the next several years.

On the other hand, Canada shipped $4.7 billion worth of chemicals to the U.S. in 1990—a whopping 69% of all its chemical exports. It already has a three-year-old free trade agreement with the U.S. Despite its naysayers, the Canada-U.S. trade agreement has provided Canada's chemical industry with such benefits as preferential tariffs and, generally, better and more secure access to its critically important U.S. market.

The feeling runs deep in the Canadian chemical industry that NAFTA negotiations could potentially erode the market access benefits that it has achieved from the earlier bilateral trade agreement. And the industry wants to make sure that its marketing muscle in the U.S. isn't atrophied by a surge of new competition from Mexican chemicals entering the U.S. on terms better than Canadian chemicals already enjoy.

So guess which tactic—offense or defense—looms uppermost in the collective minds of the Canadian chemical industry. As far as NAFTA negotiations are concerned, the industry has taken a page out of professional football's playbook—the emphasis is on defense.

True, any increased chemical trade between Canada and Mexico that may be triggered by NAFTA would benefit the Canadian chemical industry. But that's a long-term proposition.



a Converted from Canadian dollars to U.S. dollars on the basis of $1.00 U.S. = $1.14 Canadian. **Source:** Statistics Canada

The immediate concern is protecting the marketing turf it has battled to win in the U.S. and to make sure that the U.S. does not use the NAFTA negotiations to reshape the existing free trade agreement to Canada's disadvantage. Make no mistake: Canada's chemical industry unequivocally supports NAFTA. But Jean M. Belanger, president of the Canadian Chemical Producers' Association (CCPA), says the industry doesn't want to see anything in NAFTA that dilutes the gains it has made in the existing trade pact. "We don't want to see the free trade agreement become unraveled," he says.

This attitude is a microcosm of the attitude that exists in almost all of Canadian industry—and in the Canadian government. When Mexico and the U.S. initiated their bilateral free trade talks, Canada had two options. It could remain outside and look in at the Mexican-U.S. negotiations. Or it could join in the trade talks, making them a trilateral affair. It also could have negotiated its own bilateral trade agreement with Mexico, just as the U.S. was then doing. But that never was much of an option. In essence, remaining out of the negotiations wasn't much of an option either. This would have put the U.S. in the advantageous position of being the only country with tariff-free access to markets in all three North American countries.

Richard G. Lipsey, professor of economics at Simon Fraser University in Burnaby, British Columbia, says a bilateral Mexican-U.S. agreement also would push hemispheric free trade toward a "hub and spoke" arrangement. By this, he means that the U.S. would be a "hub," with separate trade deals with as many hemispheric nations as decide they want to become "spokes." The fear: The U.S. would be able to play one bilateral trade partner off against another.

Although Canada's immediate benefits from joining the U.S. and Mexico in the trade talks will be limited, the costs of not joining would have been significant. First, in a Mexico-U.S. only pact, Mexico would have gained some measure of preferred access to the U.S. market, just as Canada did under the Canada-U.S. trade pact. That would have meant tougher competition for Canadian companies in their crucial U.S. market.

Belanger: doesn't want gains diluted

As a nonparticipant, Canada would not have been able to counter any special concessions that Mexico may have received. And Canadian companies would not have been able to gain as much access to inexpensive Mexican raw materials and products as their U.S.-based competitors. Remaining on the outside, Canada would have had to react to whatever came out of a trade deal between its two North American neighbors.

Canada's exports generate almost 30% of its income and employment. And, for a country that lives so much by trade, repercussions such as these are unthinkable. As Bentley points out, until the free trade agreement with the U.S., Canada was the only industrialized country besides Australia and New Zealand whose industries did not have free access to a market of at least 100 million people. The U.S. domestic market is 240 million people. The Japanese market is 120 million people. The combined market of the European Community and the European Free Trade Association is 360 million people. The Canadian domestic market is 27 million people.

With its small domestic market and such a large share of its national income dependent on exports, says Bentley, market access is a key issue for Canada and its exporters. The bilateral trade agreement with the U.S. gives Canadian exporters virtually free and secure access to a market large enough to justify world-scale plants. Now that Canada is a part of the NAFTA negotiations, the trick will be not to lose it.

Canadian companies, including chemical companies, overwhelmingly support the government's decision to join in NAFTA negotiations. Before that decision was made, the Canadian Manufacturers' Association surveyed its members. Of the 323 Canadian companies responding, 88.2% said they favored joining the trade talks. Only 4.6% thought that Canada should stay out—this although only 19% of those companies export to Mexico and only half of them believe that Mexico will become an increasingly attractive market for them during the 1990s. And the Canadian Chamber of Commerce adopted a resolution supporting Canadian participation in the free trade talks.

So there's no doubt that industry support for Canada's participation is strong—and widespread. Yes, there was—and still is—some opposition to Canada's participation in NAFTA. For the most part, this opposition is based on environmental issues, or the fear of cheap Mexican labor taking jobs away from Canadians.

However, compared with the uproar in Canada over the U.S. free trade agreement a few years ago, the opposition to NAFTA is tame and relatively muted. One reason is that now that the U.S. pact is a fait accompli, most of the damage already has been done in the eyes of Canadian free trade opponents.

Meanwhile, there are other, much more pressing issues to command the Canadian public's attention. The still-limp economy is one of them. There's also the highly charged and controversial constitutional issue and the possibility of Quebec's seceding from Canada.

Along with other business groups, CCPA, the Canadian chemical industry's trade association, also is glad to see Canada taking part in NAFTA negotiations. "We believe strongly that Canada should be at the table when there's anything going on that may impact our industry," says Belanger.

CCPA says that one of Canada's primary objectives in NAFTA negotiations should be to get Canadian exporters ensured access to the Mexican market "in a fair and reciprocal manner." That's a logical objective, but not a very important one, as far as the Canadian chemical industry is concerned.

Canada's chemical trade with Mexico is small in both directions. In addition to the small chemical export figure for 1990 of only $15 million, Canada imported only $12 million worth of chemicals from Mexico. Two thirds of those imports are organic chemicals, not surprising since they come from a country whose chemical strength lies in petrochemicals. Canada's chemical exports to Mexico are much more diverse, with most of the emphasis on synthetic elastomers, plastics, and resins.

Not only are Canada's chemical exports to Mexico small, their growth rates are nothing to brag about. Canadian chemical exports to Mexico actually dropped an average 9% per year between 1985 and 1990. Throughout all of the 1980s, they grew at a paltry 0.6%-per-year rate. Obviously, most of the growth occurred in the early eighties. Chemical imports from Mexico have grown, rather than declined, since 1985, but they have grown at only an unimpressive 1.5%-per-year clip.

Even assuming that NAFTA triggers a generous 10% average annual growth rate in Canada's chemical trade with Mexico, chemical exports still would be only $39 million by the year 2000. Chemical imports would be only $31 million. That's hardly the stuff upon which world-scale, export-oriented plants are built.

No wonder Belanger says that "Canadian-Mexican chemical trade is not significant." No wonder the virtually unanimous attitude in the Canadian chemical industry is that the potential for increasing chemical exports to Mexico is limited. It's limited because Mexico itself is a large chemical producer and because U.S. chemical companies have geographical and cost advantages when it comes to exporting to Mexico.

Sigurdson: downstream area is problem

C&EN staff photo

And no wonder few in the Canadian chemical industry are prodding their negotiators to put much emphasis on "offensive" tactics in the NAFTA negotiations. The bottom line for Canadian chemical companies: There's little to gain in the Mexican market, but plenty to lose in the U.S. market.

As a result, the fundamental and key plank in CCPA's position paper on NAFTA calls for extending the Canada-U.S. free trade pact to include Mexico "in a manner that minimizes the need for additional bilateral adjustments between Canada and the U.S." In other words, use the Canada-U.S. trade agreement as the basis for NAFTA negotiations and extend the agreement to include Mexico in a fair and equitable manner.

Belanger stresses that the NAFTA negotiations must not compromise the letter or intent of the Canada-U.S. trade agreement in any way. Rather, they should refine and extend the original agreement. Belanger says that NAFTA negotiations should be used to address areas left unresolved by the original Canada-U.S. trade pact—for example, intellectual property and transportation services. NAFTA trade talks also might try to strengthen the free trade agreement in other areas, such as dispute settlement mechanisms.

Although Mexico is one of Canada's least important trading partners, the U.S. is by far its most important. In 1990, almost 75% of Canada's exports went to the U.S. About 65% of its imports came from there.

In chemicals, the story is the same. Canada's chemical exports to, and chemical imports from, the U.S. represent 69% and 75% of the total, respectively. Equally important, Canada's exports of chemicals to the U.S. have grown an average 8% annually between 1985 and 1990. Imports have grown an average 9% per year. Considering that there were some lean economic years during that period, those growth rates are even more satisfying. Certainly some, if not most, of the credit for this growth in chemical trade between the U.S. and Canada must go to the trade agreement that exists between the two countries.

These statistics help explain why the Canadian chemical industry, along with most other industries in Canada, did not want to see a bilateral U.S.-Mexico trade pact that either of those countries could have used to gain leverage against Canada. And they help explain why Canadian chemical companies attach so much importance to using the free trade agreement with the U.S. as a model for the embryo NAFTA.

Just how severe Mexican competition would have been for Canadian chemical producers under a Mexican-U.S. bilateral agreement, and how severe it will become under NAFTA, is difficult to tell. It could, in fact, turn out to be a nonissue.

Much of Mexico's chemical strength lies in the petrochemical sector, just as Canada's does. Canada has lost much of the feedstock cost advantage it enjoyed in the early 1980s. But it still enjoys a considerable cost advantage in shipping petrochemicals to western, midwestern, and northeastern U.S. markets.

This prompts James Sigurdson to wonder where Mexican petrochemicals will fit into the U.S. market. Sigurdson, managing director of the consulting firm of Law, Sigurdson & Associates in Toronto, notes that petrochemicals from the U.S. Gulf Coast can move northward "a certain distance," while Canadian petrochemicals can move southward "a certain distance." Geographically, he asks, where will Mexican petrochemicals fit into the U.S. market? He believes that, even with NAFTA in place, competition for Canadian petrochemical producers will come primarily from the U.S. petrochemical industry, which is exactly where it comes from now.

Sigurdson suspects that a bigger problem for Canadian chemical companies may lie in the downstream area—in such products as fabricated plastics and specialty chemicals. These products are more labor-intensive than upstream petrochemicals. And Mexico's labor costs are, of course, much lower than they are in Canada. Thus, as Mexico's chemical industry becomes more sophisticated and starts producing chemicals further down the product stream, it could become a more formidable competitor for Canadian producers.

This scenario may take time to develop, however. Sigurdson says marketing these types of products is becoming a matter of finding "niches." Even commodity resins and chemicals such as ethylene glycol now come in so many different grades and specifications that they are approaching "specialty" status. This kind of grade rationalization and the cost of "grade switching" is an ever-growing problem for chemical companies. But it is a problem in which Canadian and U.S. chemical companies have a big edge over Mexican companies.

Such analyses notwithstanding, there still remains the overriding concern that if Mexico gets to enjoy free trade status with the U.S., competition from the Mexican chemical industry will become more intense, whatever its quantitative level. And the Canadian chemical industry thinks that the best way to position itself defensively against that competition is to persuade NAFTA negotiators to use the beneficial existing free trade agreement as its model.

The existing pact, for instance, could serve as a model to develop NAFTA's rules of origin, which CCPA definitely wants included in NAFTA negotiations. These are rules that define the country from which an import originates. This is important in a regional trade pact such as NAFTA because members of the pact logically want to derive most of the pact's benefits. They want to prevent a third-party country from exporting a product to, say, Mexico, where it may enjoy trade preferences, then reexporting it to Canada. The third-party country may not have the same trade preferences in Canada that it has in Mexico, but its exports can sneak into Canada using the trade preferences that Mexico receives from NAFTA.

Consequently, CCPA wants rules of origin written into NAFTA that define those products that will be entitled to duty-free treatment when they are exported from one NAFTA country to another. Products traded duty-free under the agreement should be produced in one of the countries, both of them, or all three of them.

Setting rules of origin, however, requires some balance. CCPA notes that products made from offshore raw materials should qualify for duty-free treatment if they satisfy specific tests. For instance, the rules might require that an appropriate amount of value-added processing be done in one of the NAFTA countries before the product is exported to another NAFTA partner. At the same time, the rules must not be so strict that they offset the benefits provided by other sections of NAFTA.

For chemicals and chemical products, the Canada-U.S. trade agreement specifies that products made with offshore raw materials qualify if they have been "sufficiently changed" in either the U.S. or Canada (or both) so that they are classified differently from their raw materials. Generally, chemicals are classified in chapters 28 through 39 of the harmonized tariff system. Thus, if the raw materials are classified outside these chapters and the product is classified within them, it qualifies for duty-free treatment.

However, if the transformation process results only in a change from one subheading within those chapters to another subheading within those same chapters, then the product must also satisfy another test. At least 50% of its value must be added in Canada or the U.S. (or both). The trade agreement also contains a number of other specific rules for chemicals and chemical products to supplement these basic requirements.

CCPA believes that having these trade rules form the basis for rules of origin under NAFTA would avoid the confusion and complexity of formulating a completely new set of rules.

The association points out that the rules of origin contained in the existing trade agreement are carefully designed to reflect how chemicals are produced in the U.S. and Canada. It also points out that chemicals are produced the same way in Mexico as they are in Canada and the U.S. Thus, CCPA argues that the existing rules should be adopted "as is," with room for "adjusting details" where necessary.

Under the existing pact, it's possible to change the rules of origin if a new or different process for producing chemicals makes it necessary. CCPA thinks that this, too, should be included in the NAFTA rules, along with the consultation procedures provided in the existing agreement. In particular, the association wants NAFTA to include assurances that the regulations governing certificates of origin are fully enforced.

The Canadian chemical industry's attitude on tariffs and nontariff barriers is pretty straightforward. It wants NAFTA to eliminate tariffs on a broad range of chemicals and to reduce nontariff barriers as much as possible. CCPA says an agreement that achieves only "partial" tariff cuts or leaves a "residue" of important nontariff barriers will not achieve what it sees as NAFTA's logical goals. For CCPA, three so-called market access provisions are absolutely essential—complete removal of all barriers to legitimate and fair trade; a guarantee that they won't be reimposed; and a guarantee that new barriers won't be erected in their place during the life of NAFTA.

Basically what the Canadian chemical industry is proposing is "national treatment" of one country's products by another. This means that NAFTA should not allow any of the three countries to adopt internal rules that replace other trade barriers and that favor its own domestic products.

C&EN staff photo

Poisson: government must level playing field

Canada's chemical output tops Mexico's, but lags U.S.'s

Thousands of metric tons	Canada	Mexico	U.S.
Sulfuric acid	3311	3974	40,171
Ethylene	2425	1370	17,001
Ammonia	3602	2632	15,386
Sodium hydroxide	1651	429	10,605
Propylene	766	366	10,037
Chlorine	1542	387	9,925
Benzene	765	320	5,380
Methanol	1884	210	3,624
Toluene	427	368	2,767
Xylene	514	404	2,586
Butadiene	192	21	1,433
Carbon black	178	125	1,302
Polyethylene, low density	1167	348	5,071
Polyethylene, high density	364	176	3,778
Polystyrene	215	130	2,273

Sources: Statistics Canada, ANIQ (Asociación Nacional de la Industria Química), U.S International Trade Commission, U.S. Bureau of the Census

Tariffs, of course, are part of virtually every trade negotiation. NAFTA is no exception. Over the years, tariffs have lost a lot of their importance as a protectionist device in Canada and the U.S.—and in Mexico as well. Like the U.S., Canada grants duty-free treatment to products from qualified developing countries. In the U.S., the program is called the Generalized System of Preferences (GSP). In Canada, it is the Generalized Preferential Tariffs (GPT). Canada, says one government official, has a long list of GPT products, including Mexican products. Canada's GPT, he says, is much more liberal than the U.S.'s GSP. About 98% of Canada's chemical imports from Mexico enter the country under GPT. In the existing free trade pact, Canada and the U.S. have agreed to eliminate tariffs on trade between the two countries in stages, primarily over a period of five years. In some cases, the two countries have accelerated the staged tariff cuts and already have eliminated duties on many products, including chemicals.

Mexico, too, has reduced tariffs considerably since it joined the General Agreement on Tariffs & Trade (GATT) in 1986. For many chemicals, duties are 15% or less, a far cry from the high rates that existed in the early 1980s. And many chemicals, among them styrene, acrylonitrile, and polyethylene, enter Mexico duty-free.

CCPA thinks Mexican duties on chemicals should be "bound" at these lower rates; that is, raising them would be forbidden. Then, these bound rates should be used as a starting point for negotiating further tariff cuts (or eliminating them completely) in NAFTA negotiations. In some cases, Mexico's effective tariff rates are even lower than the bound rates. In these cases, CCPA wants to see the lower, effective rates used as the basis for NAFTA negotiations.

NAFTA, says Belanger, also should provide a phase-out period, but a limited one, for eliminating tariffs, just as the earlier pact does. This would allow companies time to adjust to the tougher competition that comes with tariff-free trade. Under the existing trade agreement, chemical tariffs can be eliminated in one of three ways: immediate elimination where Canadian and U.S. companies agree to it; elimination over a five-year period (the case for most chemicals); and elimination in 10 annual steps in those few cases where it's justified.

For chemicals, says CCPA, similar formulas could be devised in NAFTA. It opposes any "protracted" phase-in period for cutting tariffs. And CCPA insists that the schedule for eliminating chemical tariffs should be the same for all three countries. This won't sit well with leaders in the Mexican chemical industry. They think that, as a developing country, Mexico should get longer phase-in periods than the U.S. or Canada.

Speeding up the pace of erasing tariffs has worked well under the U.S.-Canada agreement. But CCPA thinks NAFTA can—and should—do an even better job. Under the existing agreement, a company can block accelerated tariff cuts on a product if it produces that product, regardless of how little it makes or how insignificant the company is in the overall business. That has already happened.

CCPA would like to see acceleration rules in NAFTA that establish a "fair and equitable basis" for the degree of producer support needed in the three countries to proceed with an accelerated tariff cut. In effect, it wants to prevent one small producer from upsetting the applecart for the majority of its competitors who may favor accelerating a tariff cut.

Reducing and eliminating tariffs encourage trade, but their benefits can be eroded by nontariff barriers such as import or export restrictions. The Canada-U.S. agreement affirms GATT obligations not to prohibit or restrict imports except under strictly defined circumstances. CCPA thinks NAFTA should do the same thing. Other than for very special exceptions, it wants NAFTA to eliminate nontariff barriers immediately or phase them out over a reasonable period of time.

CCPA singles out export taxes as a particularly disruptive nontariff barrier that NAFTA should prohibit. And any NAFTA pact on nontariff barriers should require Mexico to eliminate its import licensing requirements. In fairness, Mexico has come a long way in abolishing import licenses. But some still exist, including some on chemical and petrochemical products.

The Canada-U.S. trade agreement, says Belanger, also would be an appropriate model for setting up a dispute settlement mechanism in NAFTA. And all three—Canada, the U.S., and Mexico—agree that NAFTA should have one. "The dispute-settling mechanisms provided [in the existing trade agreement] are working well, and we believe they should be incorporated into NAFTA," adds Nova's Bentley.

The existing agreement sets up five-member dispute settlement panels and imposes specific deadlines for them to reach a decision. Panelists are chosen from preestablished rosters. It also sets explicit, relatively short time limits on each step of the process—consultation, conciliation, arbitration, and settlement.

So far, neither Canadian nor U.S. chemical companies have had any direct experience with these dispute settlement provisions. Those in industries that have experience suggest NAFTA negotiators should consider establishing a small, permanent secretariat for the joint commission that will oversee the trade agreement. They also wonder if the dispute settlement process could be improved by setting up a permanent tribunal under NAFTA instead of the ad hoc panels that the U.S.-Canada agreement provides. Whichever way it goes, the nationalities of the panelists will have to be reconsidered because three, not two, nations will be involved in NAFTA. CCPA says it will watch how these issues develop as NAFTA negotiations proceed.

The U.S.-Canada agreement also has special rules to settle disputes over antidumping and countervailing duty issues. The Canadian chemical industry considers such issues important because its exports to, say, the U.S. can be adversely affected by how the U.S. applies its trade remedy laws, such as antidumping and countervailing duty laws.

Normally, disputes in such cases are settled in domestic courts. But the trade agreement substitutes a dispute settlement panel whose members are from both the U.S. and Canada. It also requires a bilateral panel to review any changes in existing trade remedy laws and establishes working groups to develop new trade remedy laws that benefit both countries.

Mexico's antidumping and countervailing duty laws are similar to those in the U.S. and Canada. Consequently, CCPA says it may be possible to extend the provisions on dispute settlement trade remedy laws to Mexico under NAFTA. However, it has some reservations about using a trilateral panel to replace Mexican judicial review decisions. Why? Because it is not yet certain how Mexican law is being applied and whether it is being applied correctly. CCPA suggests that Mexican, U.S., and Canadian negotiators may have to develop additional guidelines for the panels to use when they review Mexican decisions under its trade remedy laws.

But CCPA hesitates to make specific suggestions, again because none of the trade remedy panels formed so far under the U.S.-Canada pact have involved chemicals.

The association's recommendations are less tentative when it comes to protecting intellectual property. It wants intellectual property rights covered under NAFTA. Its primary interest is patent protection. "There's a strong link between effective patent protection and innovation in the chemical industry," says Belanger.

According to CCPA, each of the NAFTA countries should be required to have adequate and effective intellectual property laws. At the same time, it doesn't want to see those laws become barriers that hinder fair access to technology, as occasionally happens.

Both Canada and Mexico rely on a system of compulsory licensing. And CCPA thinks it should be possible to continue these systems under NAFTA as long as the agreement provides a way to protect against possible abuse.

Along with such things as tariffs, nontariff barriers, and rules of origin, yet another issue has become entwined in international trade negotiations. That issue is foreign investment. It is a major issue in the Uruguay round of multilateral trade negotiations under the auspices of GATT. And it will be an issue in NAFTA, because any trade agreement that combines Canada, Mexico, and the U.S. into a free trade area of 360 million consumers and an annual output of $10 trillion is bound to have an impact on investment flows.

Canada's direct investment in Mexico, and vice versa, is limited. Mexican holdings of Canadian productive assets are virtually nonexistent. And Canada's investment in Mexican manufacturing industries is about $500 million. By comparison, U.S. direct investment in Mexico is about $20 billion and growing rapidly. In Canada, U.S. companies owned $9.7 billion worth of Canadian chemical assets—about 47% of the total—at the end of 1988.

A trilateral free trade pact probably won't do much to stimulate Canadian chemical investment in Mexico. Most of Canada's large chemical companies are subsidiaries of foreign multinationals, primarily multinationals based in the U.S. Deciding whether to invest in Mexico will be done in corporate headquarters, not in Canada. And the money will come from corporate headquarters, not from Canada.

Organics dominate Canada's few chemical imports from Mexico . . .

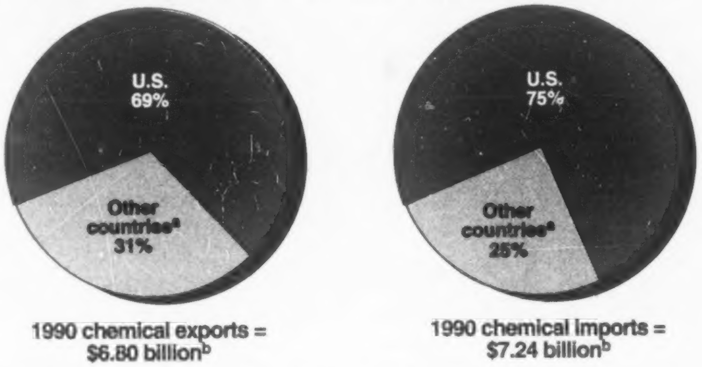
$ Millions[a]	1990 chemical imports U.S.	 Mexico	 Others
Inorganics	$ 646.5	$ 0.3	$ 496.5
Organics	1167.1	7.9	641.1
Fertilizers & fertilizer materials	160.9	0	31.0
Synthetic & reclaimed rubber	218.6	0.2	27.1
Plastic materials, not shaped	1168.6	2.1	155.3
Plastic film & sheet	366.5	1.6	74.9
Other plastics basic shapes & forms	360.5	0.2	68.4
Paints & related products	235.5	ns	23.9
Other chemical products	1118.9	0.3	263.5
TOTAL	**$5442.9**	**$12.5**	**$1783.0**

. . . but Canada's small chemical exports to Mexico are more diversified

$ Millions[a]	1990 chemical exports U.S.	 Mexico	 Others
Chemical elements	$ 143.0	$ 0.1	$ 105.0
Other inorganics	894.4	0.3	0.1
Organics	1082.5	2.5	689.6
Fertilizers & fertilizer materials	863.2	1.7	585.3
Synthetic rubber & plastic materials	832.1	4.7	479.7
Plastics basic shapes & forms	443.2	3.8	36.5
Other chemical products	437.3	1.1	89.4
TOTAL	**$4696.1**	**$14.5**	**$2091.5**

Note: Numbers may not add because of rounding. **a** Converted from Canadian dollars to U.S. dollars on the basis of $1.00 U.S. = $1.14 Canadian. **ns** = not significant.
Source: Statistics Canada

U.S. accounts for bulk of Canada's exports and imports



a Includes Mexico, 0.2%. b Converted from Canadian dollars to U.S. dollars on the basis of $1.00 U.S. = $1.14 Canadian.
Source: Statistics Canada

Nova is one of the few major Canadian chemical companies that is not a subsidiary of a foreign company. Armando Notte, manager of government relations in Nova's Ottawa office, says his company might consider investing in Mexico if the investment climate were right. But Nova is more concerned about its exports to the U.S. than investing in Mexico.

About 70% of Nova's polyethylene production, for instance, is exported and much of it goes to the U.S., says Notte. That's where the company's major concern lies. If it has to compete for the U.S. market against Mexican companies in the future, it wants to make sure that the competition is not unfair.

Nevertheless, CCPA says it wants NAFTA to include investment provisions that treat investors "in a fair and predictable manner." This will allow investments to flow freely among the three NAFTA countries.

CCPA's Belanger notes that Mexico's new foreign investment policy, introduced in 1989, is not all that different from Canada's investment policy. Therefore, CCPA contends that NAFTA should incorporate the existing trade agreement provisions that give national treatment to foreigners who establish new businesses in a country.

However, Canada retains the right to review cases in which U.S. companies acquire existing Canadian companies if the investment is $150 million (Canadian) or more. CCPA thinks this same threshold should be considered for NAFTA.

Like its counterpart in the U.S., the Canadian chemical industry wants something done about current restrictions on foreign investment in the Mexican chemical industry. The Mexican constitution reserves production of primary petrochemicals solely for the government-owned Petróleos Mexicanos (Pemex). Foreign investment in secondary petrochemicals is limited to 40%. There are no restrictions on foreign investment in the new category of so-called tertiary petrochemicals.

These restrictions are a contentious and politically charged issue (C&EN, Sept. 9, 1991, page 7). Mexico's constitutional restrictions notwithstanding, CCPA thinks NAFTA should at least explore the possibility of reclassifying even more petrochemicals than Mexico already has from primary to secondary, and from secondary to tertiary. One other possibility is that Mexico could establish a "threshold review system," similar to the one in Canada. Mexico would review foreign investments in petrochemicals only after they exceed a predetermined amount of money.

The question of foreign investment in Mexican petrochemicals is part of a larger and equally contentious issue of energy. The Mexican constitution restricts petroleum ownership to Mexican nationals. And Mexico's NAFTA negotiators have said that issue is not negotiable.

CCPA agrees that the NAFTA negotiations must respect Mexico's constitutional framework. But it also insists that the negotiations must make certain that petrochemical feedstock supply, price, and access policies do not remain or become barriers to fair competition. Any preferential feedstock policies existing in Mexico must be removed, says CCPA.

Once again, the Canadian chemical industry believes that the free trade agreement provides a good starting point for accomplishing this. In the agreement, the oil and gas sectors are specifically omitted from the investment requirements. Thus, Canada maintains sovereignty over energy resources, even though they must be sold on a nondiscriminatory basis. Although Canada, under the free trade pact, remains free to determine whether and when to allow energy exports and may continue to monitor and license those exports, the pact stipulates that the U.S. must get proportional access if Canada imposes emergency export controls on energy products. These and other energy provisions of the trade agreement, says CCPA, could be adopted in NAFTA without raising constitutional issues for Mexico.

Understandably, the Canadian chemical industry is attaching a lot of importance to NAFTA negotiations. However, some of its problems lie not at the negotiating table, but on Parliament Hill in Ottawa.

Raymond Poisson, manager of government affairs for Dow Chemical Canada, points out why. Dow Canada supports NAFTA, says Poisson. But he adds that the Canadian government must take its own steps to "level the playing field" of international trade for the Canadian chemical industry.

In Canada, interest rates are high to combat inflation. This increases the cost of borrowing. As a result of the high interest rates, the Canadian dollar is exceptionally strong. But a strong Canadian dollar penalizes Canadian exporters when they try to compete in international markets.

There are indications Canada is slowly coming out of recession, but the fear persists that it may experience a "double dip" right back into it. The Canadian deficit is extremely high. Taxes are too.

So, says Poisson, the message to the Canadian government is clear: Do all you can to correct the economic situation in your own ballpark. Without that, no NAFTA agreement, however it's structured, will do much to help the Canadian chemical industry. ☐

Strong TiO_2 demand draws Du Pont to Europe

Du Pont has its sights firmly set on becoming a producer of titanium dioxide in Europe. Precisely how it will go about making its plans a reality, or when operations will start up, isn't fixed. But there is no lack of resolve.

"There are two ways we could get there," says Dennis H. Reilley, vice president and general manager of the company's white pigment and mineral products division, who gave a briefing on the issue in London. "We could buy a piece of land and build our own plant. However, when one looks at the supply and demand picture in the industry right now, adding new capacity additional to what already is planned is not something that gets one overwhelmingly excited about it.

"That leaves us with the option of making an acquisition. For the moment, at least, that is where our primary emphasis is. We are looking at all reasonable opportunities. If we clearly can't find an acquisition that makes sense to us, we'll certainly give full consideration to building.

"We're trying to avoid setting a deadline for ourselves, because that tends to drive one to make decisions that one might regret at a later date. We are being very particular about what we would buy, and how much we would be willing to spend." He doesn't categorically rule out the likelihood of linking up with an established producer in Europe. But as he puts it, "We are not thinking about a joint venture or any type of partnership operation at this time."

C&EN staff photo

Reilley: looking for an acquisition

Some of the big names on the European chemicals scene are among the eight companies that operate the 17 titanium dioxide production units throughout Europe with an overall annual capacity of about 2.66 billion lb. ICI, through its Tioxide subsidiary, is the largest. Its plants in France, Italy, Spain, and the U.K. have a combined annual capacity rated at 904 million lb (C&EN, June 10, 1991, page 33). NL Chemicals is second largest with some 541 million lb annual capacity spread among Belgium, Germany, and Norway. Bayer, Rhône-Poulenc, and SCM each has capacity on the order of 264 million lb per year.

Existing operations in Europe, however, share a big disadvantage from Du Pont's viewpoint. All except two plants use the so-called sulfate route to titanium dioxide. Du Pont, on the other hand, has opted to concentrate solely on the chloride process for making the chemical, which it pioneered 40 years or so ago.

However, this difference alone wouldn't be sufficient to rule out an acquisition. As Reilley points out, Du Pont has had experience operating sulfate plants in the past. And there is the possibility of converting a sulfate-based facility to one using the chloride approach. "We would clearly prefer to buy a chloride plant. But if we restrict ourselves just to that notion, we would narrow our focus considerably by eliminating the majority of the capacity," he says.

He cites three advantages to the chloride process. On a pound-for-pound basis, the amount of energy required is about half that needed to run a sulfate plant. The number of people involved is fewer, so productivity is greater. Probably most significant, he points out, is that the amount of waste produced is at least a fifth of that resulting from sulfate operations. "These factors combined give the average chloride producer a 10 to 20 cents-per-lb manufacturing cost advantage over the average sulfate producer," he maintains.

This undoubtedly explains why the chloride route to titanium dioxide continues to gain ground at the sulfate route's expense. Currently, slightly under half of global production uses the chloride approach, up from about a third in 1985. By 2000, Reilley believes, the figure will be closer to 60%.

TiO_2 use growing fastest in Asia/Pacific region

Billions of lb	1991	1995	% annual change
Asia/Pacific	1.276	1.573	5.4%
Latin America	0.319	0.369	3.7
Europe/Middle East/Africa	2.486	2.702	2.1
North America	2.332	2.504	1.8
TOTAL	**6.413**	**7.148**	**2.8%**

Source: Du Pont

Environmental considerations are of growing importance, particularly for titanium dioxide makers in Europe. There, legislation that sets limits on the permissible amount and nature of the process waste stemming from the operations throughout the 12 member countries of the European Community come into effect next year. "Many European sulfate producers will be required to add acid recycling, and/or acid neutralization, equipment," Reilley says. "Installation of these facilities will call for large capital expenditure, and has the potential to add 10 to 15% to manufacturing costs.

"Clearly, to operate a titanium dioxide plant is becoming increasingly harder to do in terms of meeting regulatory requirements," he concedes. But he isn't fazed by the prospect. "The road to achieving the necessary permits for the plants we are building in Taiwan and South Korea has been extremely difficult and lengthy," he points out. "We found that the [environmental] requirements there are as strict as any in the world. So we are confident that we can get permitted anywhere because the chloride process is much more favorable from an environmental point of view."

Du Pont's plants going up in Taiwan and South Korea will be completely waste-free, as is the one the company operates at Antioch, near San Francisco. "All coproducts of the process are converted to salable items. Everything that leaves our Antioch plant fits into that parameter. The plant in Delaware is about 80% waste-free. Only a very small portion of material from the process can be classed as waste.

"We deep-well waste coming from our titanium dioxide operations in Mississippi and Tennessee, and have been doing so for many years. But we clearly recognize that the public perception surrounding this is not good. So we fully intend to discontinue both of these deep-welling operations eventually."

He points to a number of uses for the waste products. Ferric chloride has established itself as a useful water treatment chemical. The iron itself has some commercial value to steel producers, and vanadium and other trace elements are being recovered. Another coproduct is offered as a dry aggregate used in road building. "We have only just scratched the surface in terms of the unique and useful needs that coproducts of the chloride route to titanium dioxide can fulfill," he contends.

Considering that Europe, the Middle East, and Africa are the geographic regions accounting for the highest share of global sales of titanium dioxide, it's surprising that Du Pont only now is getting around to siting production there. Last year, combined demand in those regions amounted to 2.49 billion lb, 39% of the 6.41 billion lb world total. Coming a close second was North America, with 2.33 billion lb (36%), followed by the Asia/Pacific region with 1.28 million lb (20%). Latin America made up the balance with 319 million lb (5%). Annual per capita consumption of titanium dioxide is highest in North America, however, at 7.5 lb against Europe's 4.4 lb value.

After some two years of soft sales demand and price decline, the titanium dioxide industry as a whole currently is running at about 86 or 87% of its installed plant capacity, Reilley says. But with indications of an upturn in use, and the likelihood that some existing sulfate-based capacity will be phased out, he anticipates that capacity utilization rates will range from 93 to 97% by 1995.

In anticipation of its future production plans for Europe, Du Pont meanwhile is taking steps to strengthen its presence on the European titanium-dioxide-based pigments and coatings scene. It has just opened a specialized customer service and technical center in Belgium. It has restructured its Europewide sales organization, and has placed managers in Budapest, Moscow, and Warsaw who call on titanium dioxide consumers throughout Eastern Europe. And it is responding to special market needs there by introducing new products geared to the European paper laminates and plastics operations, as well as pigments for the water-based coatings industry.

Dermot O'Sullivan

Rubber use expected to bounce back in 1992

Not surprisingly, the recession has put a damper on the synthetic rubber market, with demand declining an estimated 3.4% in 1991. But producers of synthetic rubber say they see light at the end of the tunnel.

This year, total North American synthetic rubber consumption—including thermoplastic elastomers—is expected to recover, with growth of 3.7% over 1991, which will restore it to its 1990 level of about 2.77 million metric tons. Consumption then is forecast to rise at an average annual rate of 2.1% through 1996, according to the International Institute of Synthetic Rubber Producers (IISRP) in Houston, which has just issued its five-year forecast. "After the anticipated turnaround in the economy, growth in synthetic rubber is expected to return to traditional rates of growth," says William E. Tessmer, managing director of IISRP.

In particular, thermoplastic elastomers are expected to outpace total synthetic rubber growth by posting a 7% annual growth rate through 1996, says the institute. Substantial gains are also expected for certain specialty elastomers (such as acrylic rubber, polyester elastomers, butadiene copolymers, ethylene copolymers, modified polyethylenes, and fluorinated elastomers), polybutadiene, carboxylated styrene butadiene rubber latex, and ethylene-propylene rubber. However, for the five-year period through 1996, IISRP projects that consumption of all elastomers, except polychloroprene, will grow some on an annual basis. Because polychloroprene is being replaced by nitrile and thermoplastic elastomers in some high-temperature applications, consumption is expected to remain relatively stable at 77,000 metric tons, says Richard Killian, IISRP's administration director.

Natural rubber had an even rougher 1991 than its synthetic counterparts, with consumption dropping 5.3% from 1990 to about 846,000 metric tons. However, natural rubber is also expected to recover this year, with a 5.1% increase in consumption to 889,000 metric tons. In the forecast period 1990–96, IISRP expects natural rubber consumption to return to a traditional growth rate of about 1.7% annually, reaching consumption of 987,000 metric tons in 1996.

Susan Ainsworth

Thermoplastic elastomers to dominate rubber growth in North America

Consumption, thousands of metric tons	1992	% change 1991–92	1996	% annual change 1990–96
Styrene-butadiene rubber				
Solid[a]	766	4.5%	818	0.7%
Latex	50	4.2	54	1.3
Carboxylated latex	501	2.5	552	1.7
Polybutadiene	410	3.5	452	2.2
Ethylene-propylene	199	4.5	257	3.2
Polychloroprene	75	2.7	77	–0.2
Nitrile butadiene rubber				
Solid	71	0.4	73	1.1
Latex	37	0	38	1.1
Other synthetics	376	3.9	423	1.8
Thermoplastic elastomers	286	5.1	389	7.0
TOTAL SYNTHETIC RUBBER	**2770**	**3.7%**	**3133**	**2.1%**
Natural rubber	889	5.1	987	1.7
TOTAL RUBBER	**3659**	**4.1%**	**4120**	**2.0%**

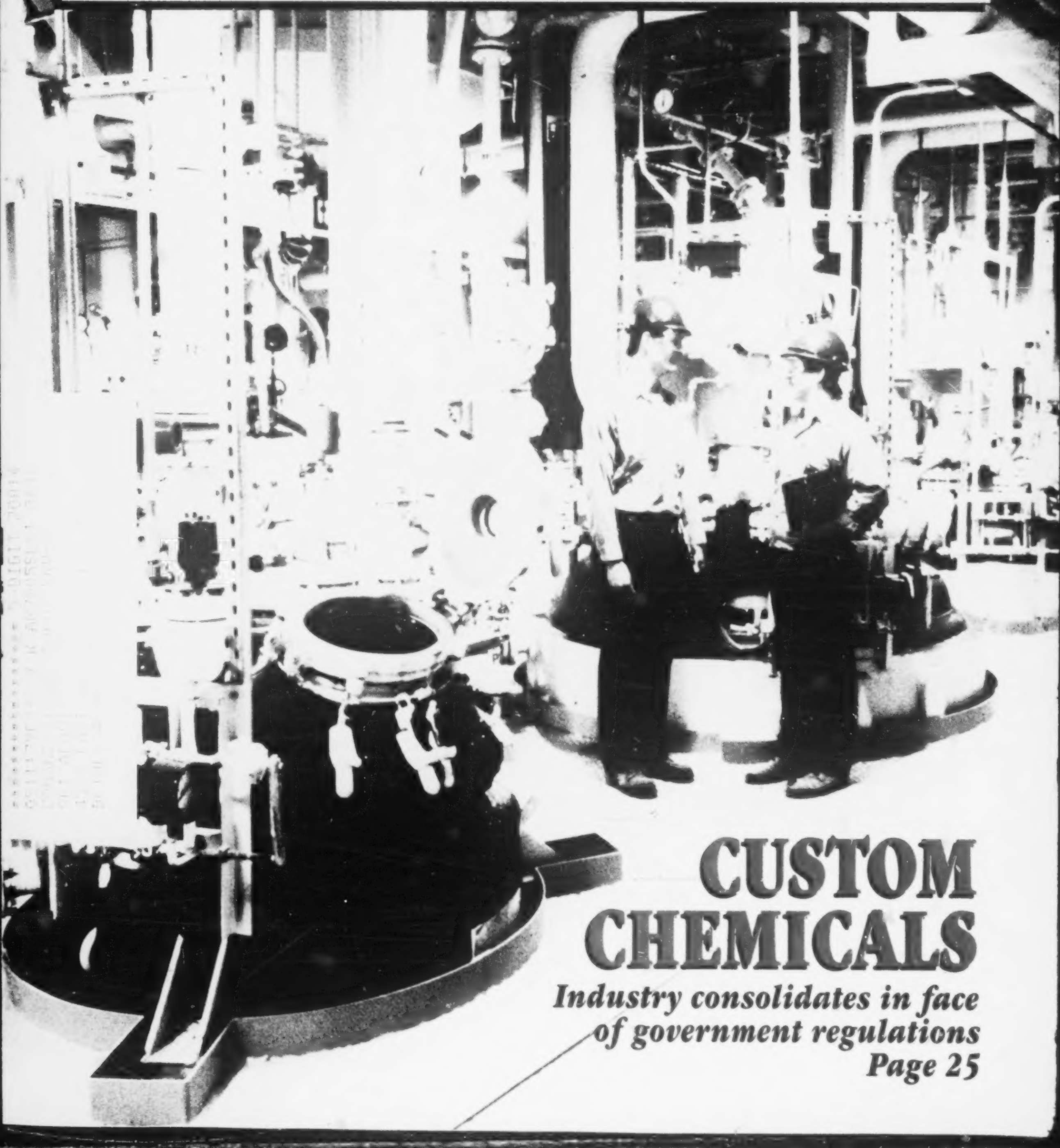
[a] Includes high styrene. **Source:** International Institute of Synthetic Rubber Producers

CHEMICAL & ENGINEERING NEWS

C&EN

FEBRUARY 3, 1992

NSF USES LEGAL, SCIENTIFIC EXPERTISE IN MISCONDUCT INVESTIGATIONS PAGE 17



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Industry consolidates in face of government regulations
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- Despite poor chemical company earnings and sales in the fourth quarter of 1991, analysts are optimistic and are recommending chemical stocks. Page 5
- Congress' scrutiny of indirect costs charges continues with investigations of Superfund and Department of Energy contractors as well as universities. Page 6
- Monsanto Chemical starts program that gives employees $1000 toward purchase or lease of vehicles built in North America. Page 6

COVER: Aldrich Chemical's custom chemical facility near Sheboygan, Wis.

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BUSINESS

Chemical firms see ties with universities as important part of their research and development programs, although relationships occasionally can be strained. **Page 9**

Canadian companies are optimistic about their prospects in 1992, following a bad year for the chemical industry when pretax profits virtually disappeared. **Page 13**

Plastics packaging firm, Ametek, has profited from new proprietary blowing agents and reusable and recyclable packaging systems developed in response to concern for environment. **Page 14**

GOVERNMENT

At NSF, allegations of scientific misconduct are handled by small team of scientists and lawyers in agency operation that, unlike NIH's, has so far escaped controversy. **Page 17**

SCIENCE/TECHNOLOGY

Taiwan readies for high-tech era, with science and technology among government's top priorities and R&D budget over the past few years up an average 24% annually. **Page 21**

BOOKS

In "The Green Flame: Surviving Government Secrecy," Andrew Dequasie gives little detailed technical information about nearly 40-year-old defense-related project, but provides historical account of his personal experience. **Page 52**

ACS NEWS

Forty-six student affiliate chapters have been recognized for their programs and activities for the 1990–91 academic year by ACS's Society Committee on Chemical Education. **Page 53**

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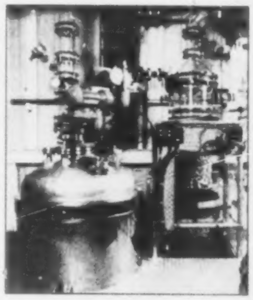

Custom chemical producers move to meet changes occurring in fine chemicals industry in their effort to stay competitive into next century. Page 25

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600, TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr $105, 2 yr $189; outside U.S. 1 yr $141, 2 yr $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

Perfluorocarbon compounds and polymers

There was a serious error in my letter on the potential hazard posed by perfluorocarbon compounds and polymers in combination with strong oxidizers (C&EN, Dec. 16, 1991, page 2). Although these compounds can burn with the release of significant energy in some circumstances, this error greatly exaggerated their theoretical hazard in high-pressure oxygen.

The corrected ideal-gas results for varying weights of two perfluorocarbons in a 110-cc bomb containing oxygen at 2000 psi are as follows:

	Grams							
	0.20	0.25	0.40	0.60	0.80	1.0	5.0	10.0
C_7F_8								
T (K)	463	502	613	750	878	998	2591	3386
P (MPa)^a	21.48	23.30	28.51	35.00	41.05	46.78	130.39	197.75
P (psi)	3115	3379	4135	5076	5954	6785	18,911	28,681
Polytetrafluoroethylene								
T (K)	374	392	446	514	578	639	1482	2090
P (MPa)^a	17.34	18.20	20.74	23.98	27.07	30.0	73.93	112.43
P (psi)	2515	2640	3008	3478	3926	4351	10,723	16,307

a Megapascal.

The results for TNT in my previous letter were correct, but they were for 19.965 g (based on 0.25 g of perfluorocarbon + 19.75 g of oxygen), not 0.43 g. The corrected pressures are much lower than the TNT results, so the comparison has little significance.

I thank Kirby Scherer and R. Bert Diemer (Du Pont Polymers) for a valuable discussion on these calculations.

Eli Freedman
Baltimore, Md.

Bottled water

A Newscripts item (C&EN, Dec. 16, 1991, page 40) referring to a *CHEMTECH* article on bottled water, noted that of the 37 waters analyzed, 24 were out of line with one or more requirements of the U.S. drinking water standards, and quoted, "It is unlikely that a survey of community water supplies would find as high a degree of noncompliance. Maybe we'd all be better off drinking tap water!"

While ACS decries the public's lack of understanding and trust of science, ACS publications should not be carrying *Reader's Digest*-grade articles. These authors either misrepresent, or do not understand, drinking water standards.

The impurities cited as exceeding the U.S. drinking water standards include: pH, chlorine, fluorine, manganese, sulfate, and barium. All of these (except barium) are secondary drinking water standards, which EPA states are "not designed to protect the public health. Instead they are intended to protect 'public welfare' by providing guidelines regarding the taste, odor, color, and other aesthetic aspects of drinking water which do not present a health risk."

Although the European Economic Community has chosen to set low guideline levels for calcium (100 mg per L), magnesium (30 mg per L), potassium (10 mg per L), sodium (20 mg per L), and chlorine (25 mg per L), these are essential minerals for which humans have substantial daily requirements. For comparison, whole milk contains (per liter) 1190 mg calcium, 130 mg magnesium, 1500 mg potassium, and 490 mg sodium. Why should a water with comparable mineral content be considered dangerous?

So let's be reasonable about water. There are plenty of other items that are truly harmful, and most people don't like the taste of distilled water anyway!

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Morton International Inc.
Woodstock, Ill.

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Corporate Execs Weigh Evolving University/Industry R&D Alliances

■ ***Although relationships have been strained at times, industry looks positively on improved ties to academia***

Ann M. Thayer,
C&EN Northeast News Bureau

The "cultural gap" between industrial and academic research continues to take on interesting new dimensions as relationships between companies and universities evolve. In the past, debate has centered largely on the inherent shortcomings of such alliances because of the different paces, outlooks, and goals in industrial and academic research. At the root of this is a mistrust and fear that academia will be subverted by commercial interests, which in turn misunderstand and misuse university research.

Changing attitudes, as expressed by chemical industry executives, suggest that alliances are moving in new directions. Among these is an apparent awareness of industry's and academia's complementary roles in R&D. Whereas companies say they have become more flexible in negotiating agreements, ironically universities are said to be moving in the opposite direction. Counter to this, universities are at the same time being pulled toward working with industry as a result of declining federal support.

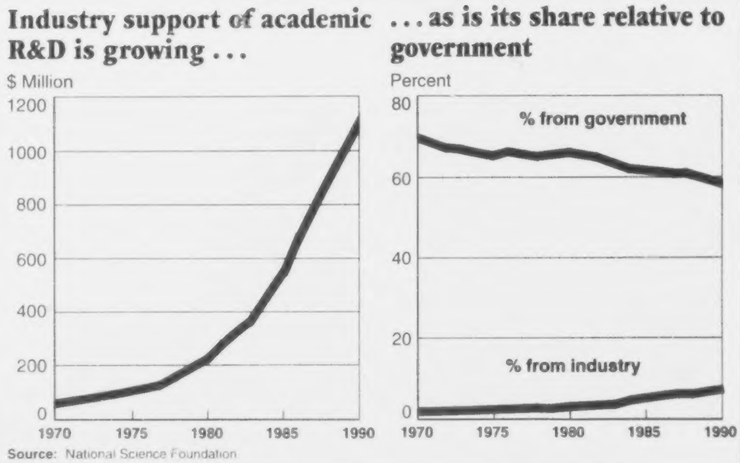
In 1990, $1.14 billion of the $16.3 billion in funding for academic R&D came from industry, according to the National Science Foundation. Although this is well below the $9.6 billion from the federal government, industry's contribution has risen from about 4% to 7% over the past decade. The federal government's contribution has fallen from 67% to 59%, while other sources of funding, except institutional sources, have remained flat.

Despite industry's increasing financial commitment to academic R&D, questions continue to arise over intellectual property rights, conflicts or lack of interest on the part of university researchers involved with commercially related research, the demand for rapid returns on investments by industry, and the function of universities to publicly disseminate scientific results versus the need by companies to retain proprietary information. The remarkably similar views of executives from six major chemical companies—Dow Chemical, Du Pont, W. R. Grace, Hoechst Celanese, Monsanto, and Union Carbide—suggest that these issues are being addressed in the way collaborations are established.

Although collaborations with universities may differ in detail, the philosophy and goals behind them are very similar. "To ignore academia is to ignore a tremendous pool of talent and creative ideas," says Frank Knoll, project manager of cooperative research, Dow Chemical corporate R&D. "There's nothing that says a company can't do that, but I think . . . it would be a poor decision." Faced with competitive pressures based on the ability to make technological advances, chemical companies see alliances as an important element of their R&D programs. There is a need for fundamental research in support of core technologies and product development, and for accessing emerging technologies as a means to stay competitive. For small companies with limited resources, such as biotechnology companies, alliances can provide a primary source of basic R&D and licensable discoveries.

"Grace has no hesitancy to start at a very fundamental level in new research fields that the company can identify as having long-term impact on our product lines," says F. Peter Boer, a Grace executive vice president and chief technical officer. "The company uses university relationships to further its total strategy when it comes to innovation, long-term research, and even some medium-term problem solving." In return, industry not only helps support basic research but, when the occasion arises, also provides the development tools to commercialize university discoveries.

"For the most part, I feel very strongly that truly basic research, and by that



Industry support of academic R&D is growing . . .

. . . as is its share relative to government

Source: National Science Foundation

I [mean] research which has as its express purpose the creation of new knowledge in a specific field, is best done in academe," says Leonard N. Baker, vice president, corporate technology at Union Carbide. The company participates in about 30 university-based consortia and has more focused research agreements with about 20 other universities. Many firms also have relationships with foreign universities as a means to tap into research developments or to have a company R&D presence overseas. "[Union Carbide] feels strongly that it has to stay on top of cutting-edge technologies in areas that are related to its core competencies," Baker adds. "These contacts are a way of focusing and leveraging the company's R&D sources in areas of potential significance to the corporation."

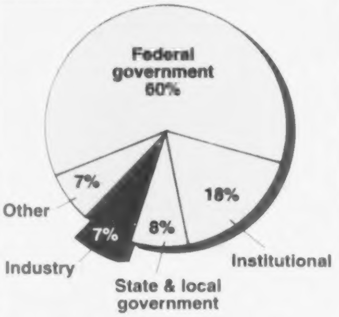
Monsanto's 10-year alliance with Washington University Medical School, one of the oldest and largest collaborations between a U.S. company and university, is an example. Deciding in 1981 to enter pharmaceuticals and realizing that it would take decades to build up an in-house effort, Monsanto looked at a university alliance as a means to access basic R&D discoveries, explains Philip Needleman, who came from the university and is now Monsanto's vice president for R&D and chief scientist.

The success of the program in its first few years accelerated Monsanto's acquisition of its Searle pharmaceutical subsidiary in 1985, Needleman believes, giving the company a development arm with which to move discoveries forward. "As to the company strategy," he says, "the university arm is an ideal complement to its own internal research program." With a second program renewal in 1990, total funding commitments reached nearly $100 million. Currently about 50 projects involving 120 university scientists are supported.

Despite a few product leads, the Washington University program needs "refinement," says Needleman, and to move away from its broad scientific goals. "We did a great job in taking care of what the university needed, and a good job of what Monsanto needed in terms of a menu [for development]," he says. "But this program only will go on if we both can succeed.

"We have had a great first decade, but [Monsanto] needs to focus more on a limited number of disease areas so that we can advance more expeditiously through discovery and toward effective therapeutic agents." Although not wanting to leave the present arrangement with Washington University, he adds that he would not choose to enter a large university agreement again. "I don't see the advantage of taking large grants into a broad program as opposed to surgically picking the specific areas the company would like to advance and develop."

Industry funds 7% of academic R&D



Fiscal 1990 academic R&D spending = $16.3 billion

Source: National Science Foundation

What is difficult to gauge is whether these alliances represent either a decreasing internal investment or an increasing overall commitment to basic research on the part of chemical companies, and the implications of this. In most cases, the alliances are separate from more straightforward licensing functions. "In the past, it's been traditional for Du Pont to bring [new] technologies in-house either by licensing patents or hiring the right researchers," says James Nottke, director of technology acquisition for Du Pont. "These days the company wants to look more broadly to see if it makes more sense to support a professor's research."

Du Pont created Nottke's position this year with the strategic goal of exploring technologies to pursue and to expand the firm's contacts with universities. Du Pont's ongoing collaborations generally have been set up on an ad hoc basis, and Nottke sees his new centralized role as initially identifying and "brokering" relationships, but then stepping back. "I will be looking for those pieces that will take us into some pioneering areas, building on some of our core competencies," he says. "Very seldom does a company really strike out in a field that it is totally unfamiliar with. It usually fails if it tries." Similarly, in the late 1970s, Dow created its centralized office in corporate R&D to help coordinate and fund interactions among Dow researchers and academic scientists and to screen proposals submitted to the company.

For companies, collaborations can be cost-effective routes to explore new technologies without committing resources or hiring staff at early, and more risky, stages of development. During recession, research objectives still can be accomplished when companies are faced with hiring freezes, thereby freeing up limited internal resources that can be applied elsewhere. To estimate the value to companies, one need only consider the relative proportion spent by companies and universities on basic versus applied research projects. "There is no company in the world that is spending what Washington University is in fundamental discovery," says Needleman. "So in academic life there is more 'bang for the buck' at the discovery level than there is in industry. Yet, what academic life doesn't do is advance that to the [ultimate product]."

A pitfall to avoid, companies have learned, is using universities for product development, something for which they generally are not equipped or necessarily interested in doing. Trying otherwise has been a criticism of industry programs with universities and generally only results in frustration on the part of the company and resentment on the part of the university. "If we find something that looks like it would fit well with our business strategy and product line, there are occasionally the temptations to use the people at the university to do the next stage of development because they are already [involved in the project]," says Nottke. "But they will always do it a little slower and without a number of the manufacturing concerns that we in industry have."

In light of this, it is no longer surprising that most collaborations by chemical companies are aimed at accessing universities' expertise in basic research. "Universities, in doing fundamental research, have two products," says Baker. "One is scientific knowledge itself and the other is the mechanism by which that knowledge is generated, and that mechanism is students." And, it is these types of relationships that companies now believe are the most successful.

For collaborations to be deemed successful, most managers say there need not be tangible results and many accept that success rates will be low. In fact, examples of actual products that have come out of chemical company and university collaborations appear limited, although some companies can cite numerous patents. "If [commercializing products] were used as a criterion, then Dow might ask the question: Is cooperative research really successful because it doesn't have a specific product to show for all this?" says Knoll. "But the company thinks that the real value is in the collaborative and creative interactions that have occurred over the years and continue to occur.

"Patents and intellectual property are an important part of the deliverables in a program," he adds, "but you get very good results very often where no patents develop." Instead, information that contributes to a basic scientific understanding in support of a company's product or technology development generally is considered the most positive result. And measuring the success of a program depends largely on the expectation level set in the very beginning.

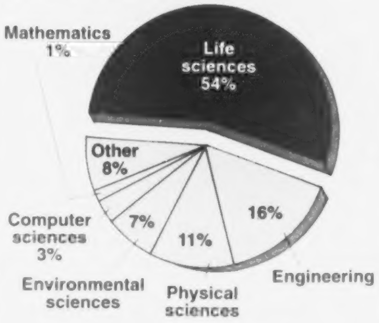
"Some companies may go in with marching orders," adds Knoll, "Dow doesn't. If you understand how universities and students and the education process work, you can't really demand that kind of thing. I think there are companies that have the mentality that [universities] are like research institutes and ask for specific deliverables, but in fact they are not contract research institutions. When you develop a university interaction, you want to tap into the creative abilities of a professor and a student and that's a variable thing."

If companies and universities can bridge the differences in outlook and pace of industrial and academic research, believes Boer, "the other problems are easy." Another factor in success is a strong common objective. "Like curing diabetes, that's a powerful objective," he explains. "Powerful to W. R. Grace and its stockholders because it has financial and social value, and powerful for a university because it has social and academic value." Development of an artificial pancreas, now in advanced preclinical trials, is one of Grace's largest programs based on university collaborations.

Collaborative projects tend to be negotiated on a case-by-case basis and therefore run a gamut of styles. An important caveat, comments one executive, is to not cross the line between research contracts that have strings attached and philanthropic grants, otherwise both their management and messages get confused. In general, projects last from one to a few years and are reviewed at various stages for renewal. "Dow usually tries to avoid multiyear commitments," says Knoll, "because it is very common to discover things that we didn't expect, so [renewing] is a very convenient way to refocus the project and it also allows us to check on progress." Based on experiences from an earlier, failed program with Harvard, Monsanto uses an external review panel in its program with Washington University.

Funding typically ranges from about $25,000 to $50,000 per project, but can go as high as $100,000 or $250,000, depending on the number of faculty members and students involved. Total investments by a company are difficult to estimate because most have a wide variety of ties with a number of universities through faculty consultants, unrestricted grants, fellowships, collaborations, and memberships in consortia.

Universities spend most on life sciences



Fiscal 1990 academic R&D spending = $16.3 billion

Source: National Science Foundation

On average, total annual funding for cooperative R&D is about a few million dollars for each company, although Du Pont and Monsanto spend a few times that amount. Although a relatively small proportion of their R&D budgets, chemical companies consider their investments as sizable and take them very seriously.

Further complicating estimates is that most funding comes from individual R&D divisions or business areas within a company, as do the initiatives to set up collaborations. An exception, but only in terms of funding, is Dow's cooperative research office, which carries the majority of costs in the first year and then splits costs with sponsoring Dow labs in later years. Having separate R&D or business areas responsible for funding operates as a system of "checks and balances" on how resources are invested, along with determining the importance of, and commitment to, specific collaborations.

A few chemical companies indicate that they may try to avoid overlapping on projects with federal funding because government restrictions can limit access to certain technologies. However, others believe that this is not a serious limitation or are willing to accept whatever restrictions may arise. "In recent years, the government has been insisting that in some federally funded contracts there also be industrial partners so that technology transfer from the university to private industry is facilitated," adds Baker.

Most companies set up some sort of research agreement or contract that deals with the disposition of intellectual property rights. Patents, if they result, frequently belong to the scientist or university under its rules, although industrial patent offices often assist in the preparation and filing of patents. Companies commonly ask for right of first refusal for exclusive licenses to university patents, although other provisions may be made with determining factors related to the area of research and level of investment by the company.

Restricting publication of results has been harshly criticized and companies find moves in this direction meet with resistance by universities, which guard this right carefully. Because more collaborations are aimed at fundamental, rather than proprietary, research, the consensus on the part of chemical company managers is that all work is publishable. It still is common for companies to ask for a period in which to review any results before they are made public, while trying to ensure reasonably prompt publication and open discussion of scientific results. "If a company is greatly concerned about proprietary information being involved," says Boer, "it shouldn't enter into a university relationship."

Despite what industry sees as an increased flexibility on its part in structuring alliances, there is a sense of more rigidity on the part of universities. Evidence of this is a move on the part of universities to retain technology, or at least the control of rights to it, say company managers. A less extreme view is taken by Carbide's Baker, who suggests only that universities have become more aware of the value of patents and that industry should be aware of this and willing to work out a few issues.

"There was a time when university patent offices were operating under some significant misapprehensions and were functioning more to protect the university from an unknown evil than to foster the commercialization of their technology," says Boer, leading to "onerous" terms. These misapprehensions were fueled by a few cases in which patents, such as the Cohen and Boyer fundamental patent on the process for inserting genetic material into bacterial plasmids, have generated large revenues for universities or researchers.

"Every university felt that it must have such things just around the corner," says Boer, "when in fact there are very few Cohen and Boyer [patents] out there. It is very important for a university to understand that the licensing terms should also be on a basis that is attractive for the industrial partner to continue the project and to take the risks toward commercialization."

However, universities are faced with increased pressures to find funding and may look to generate revenues from their patents. But companies stress that while universities may want to do this, it is time-consuming to build up patent libraries, to license technologies, or to try to develop products when they lack any real experience. "Universities don't worry about markets and product economics as they are not in the business of doing that," says Knoll. "Whereas Dow, as with any company, lives and dies by its ability to evaluate the worth of any technology in the marketplace."

"Universities often overestimate the dollar value of a discovery," says Faruq Marikar, manager for external technology at Hoechst Celanese, "and misunderstand the process of innovation in industry, which is usually incremental rather than one big leap." Contributing to this problem, he adds, is legislation that allows universities to have exclusive rights to government-funded research inventions. "Universities are trying to use the same policy on work that industry funds." In response, he explains that companies look carefully at how much, by way of licensing, university patents really are worth and, believing it unlikely that many will generate income, have become more lenient about patent rights.

Universities viewing companies only as a source of money also can be counterproductive, say chemical industry executives, but this can sometimes be related to how strong the connections are between a company and a university. "Dow tries to reach an understanding with the university that this truly is a collaborative effort with close communication between the Dow scientist and the academic scientist," says Knoll, "both contributing ideas, working closely together, and getting excited about the progress."

Another factor can be the level of management at which projects are handled. The most positive relationships and successful collaborations come about from a "bottom-up" rather than a "top-down" approach, say chemical company managers, based on the idea that people, rather than institutions, are working together. Many collaborations are initiated by individual company scientists who have a strong interest in working with a university researcher. For this reason, most also are set up on an ad hoc basis.

"I feel very strongly that 'bottom-up' is the way to go," says Boer. "Basically, you won't do very well if you don't have an internal scientist who is enthusiastic about the area of research, in essence taking responsibility for the program, and generally as knowledgeable about it as his university counterpart." Although their areas of expertise or knowledge may be somewhat differently oriented, he explains, together they make a motivated team. This feeling of teamwork also tends to create a sense of seriousness about the program and that "a company is not just talking about easy money for a few years, but that real results and a deep relationship are expected," he adds.

Proximity also can play an important role in initiating and sustaining relationships between chemical companies and universities. Close relationships with universities allow companies not only to access research developed in collaborative projects but also help to expand connections to the scientific community in general. Chemical companies ask their researchers to stay on top of developments and to be aware of leading academic scientists in areas of interest to the company both as a means to manage and improve ongoing collaborations, and to scout for new alliances.

On the chemical company side, it also is important that there are strong in-house R&D efforts to draw on, employ, or adapt work done at universities. "There is a limitation on how much technology and basic science a company can go out and acquire from the university system," says Marikar. "Ultimately it is limited not by the dollar amount, but [by] the technology expertise a company has in the way of people who can go and [work with] the university system."

Although not the main reason behind most collaborations, say company executives, alliances do provide a means to evaluate students as candidates for hiring, and students can make contact with potential employers. Hiring students who have worked in research areas of interest to a company is one way to transfer technology development in-house. And students who stay in academia also are possible future collaborators.

But overwhelmingly, chemical executives say they are not looking for individuals trained to do applied research. "We need more scientists and engineers in the U.S. to maintain our competitive capabilities," says Carbide's Baker. "And any enlightened high-tech company would much rather have highly trained, sophisticated, and versatile individuals trained in the true academic sense, but interested in applying that knowledge to commercial problems." ☐

Belanger contends that the next major cycle of global chemical investment is being planned now. It's critical, he argues, that governments restore competitive tax policies for the chemical industry as soon as possible. If they don't, "there's a very real risk that Canada will be left out of the next wave of expansion," he warns.

But tax problems aren't the only thing bothering Canadian chemical companies. Canada's exchange rate policy, which has kept the Canadian dollar strong, has hurt exports and boosted imports. Pending legislation in Ontario, including labor legislation, also worries the Canadian chemical industry.

Despite the pall overshadowing the CCPA survey, Canadian chemical companies are "cautiously optimistic" that the worst is behind them. Sales are expected to increase 5 to 6% in both value and volume. And although sales to domestic customers will inch upward only 1%, exports probably will increase 10%, including an encouraging 16% increase in shipments to the U.S.

Still, these forecasts could be overly optimistic if the hoped-for improvement in economic conditions doesn't materialize. In addition to the questionable North American economy, Europe's economy also is softening. So, too, is Japan's.

Many chemicals still are in oversupply. Among them are ethylene, polyethylene, and sodium chlorate, products that are particularly important to the Canadian chemical industry. It will take time to work off this surplus.

In time, the restructuring and adjustments that Canadian chemical companies have been making will put them in a good position to capture new business in the U.S.—that is, when business conditions there improve. One company says that, increasingly, U.S. customers are beginning to accept Canada as a "valid North American source."

According to the CCPA survey, the best hope for the long-term growth of the Canadian chemical industry lies in integrating production and markets on a "North American" basis under the Canada-U.S. Free Trade Agreement. Unfortunately, the industry believes that the benefits that should come from such tactics are threatened by the Canadian government's own economic policies.

Earl Anderson

Environmental push pays off for packaging firm

Environmental groups often attack packaging materials because the process to make them may release potentially toxic chemicals, and then, used once, packaging materials take up valuable landfill space. Ametek, a diversified manufacturer based in Paoli, Pa., believes it can answer environmental activists' objections and make good profits at the same time.

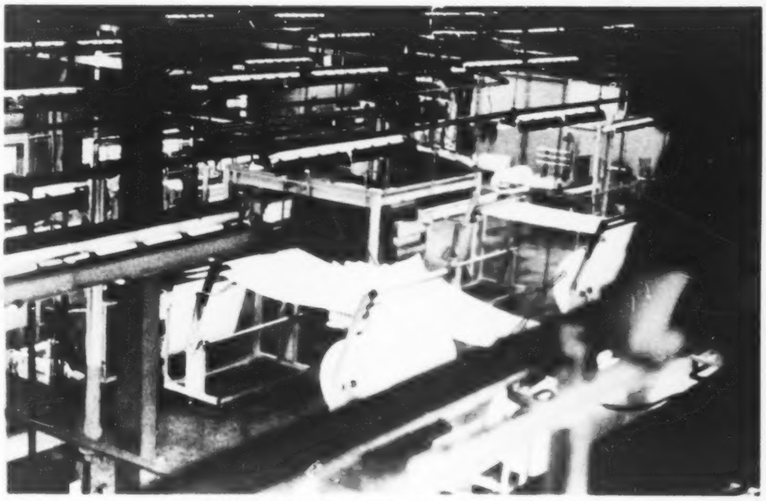
The company's Microfoam division, headquartered in Chadds Ford, Pa., had been using chlorofluorocarbons (CFCs) as blowing agents to produce polypropylene packing sheet foam for shippers of sensitive electronic equipment. Now it has replaced these CFCs with proprietary blowing agents, and has perfected a process to capture and reuse these blowing agents. Microfoam also has come up with reusable and recyclable packaging systems for furniture shippers.

Herman C. Koch, general manager of Microfoam, admits the company was under government pressure to replace CFCs in the production of polypropylene foam packaging materials. CFCs have been implicated in the destruction of Earth's protective ozone layer. Development of a replacement for CFCs began four years ago at Ametek, says Koch. As far as Ametek is concerned, the replacement blowing agents "have been a positive environmental trend."

Ametek does not, however, use a hydrocarbon blowing agent, which competing polyethylene foam sheet producers use. Hydrocarbon blowing agents are volatile and unsafe if improperly handled, Koch points out. In addition, unrecovered hydrocarbons can contribute to the formation of atmospheric smog. The environment and safety were major considerations in the three years of work Ametek invested in its proprietary blowing agent system, he says. The resulting system poses little threat to workers and is environmentally sound, he claims.

The new system allows Ametek to recover up to 99% of the blowing agents used to produce its packaging foam sheets, Koch says. Recovery and reuse not only pays for construction of the recovery system at the company's plants (a $5 million expenditure), but also justifies the higher initial cost of the blend itself, he notes. Ametek actually saves money because of the recovery and reuse of the new blowing agents.

Government and environmental groups not only have forced packaging manufacturers to change their practices, but also have had an effect on packaging users. More industrial shippers are reducing the volume of packaging materials they use, and getting rid of multilayer packaging made of dissimilar polymers. And recently enacted and impending government regulations have prompted shippers to eliminate



Ametek facility forms foam into a continuous sheet

Koch: recover up to 99% of blowing agents

unnecessary packaging, employ reusable containers, and recycle.

A good example is furniture maker Ethan Allen, Danbury, Conn. The company separates and sells used packaging to recyclers, and takes back packaging from its dealers for recycling, points out Thomas Lowery, director of packaging and engineering. It does not limit recycling to the type of polypropylene foam that Ametek supplies, but also recycles other packaging materials such as polyethylene, polystyrene, corrugated cardboard, and even wood skids—all of which have their use in packaging goods so they may be shipped safely and without blemish.

Retailer Sears Roebuck & Co. announced in November that it was working with suppliers to reduce packaging volume 25% by 1994, thereby eliminating 1.5 million tons of packaging materials by the end of 1994. Pressured in part by customers, Sears hopes not only to help reduce the nationwide solid-waste disposal problem, but also to save $5 million. Another of its goals: By the end of 1995 plastic containers used to package its products will contain 20% recycled material.

As the government, major manufacturers, and retailers put pressure on the packaging industry to reduce waste and recycle packaging materials, it is in the best interest of packaging manufacturers to respond. After all, they will want to preserve the U.S. protective plastic packaging market, which market analysts Kline & Co., Fairfield, N.J., estimates has sales of $1 billion annually and projects to grow at about 5% annually over the next few years.

Koch wants to see his company grow faster than the industry, and the key is weight reduction and reuse of shipping containers. In fact, Koch hopes sales of Ametek's polypropylene foam will continue to increase in the next five years at the current 10% average annual rate. Though declining to give precise data for competitive reasons, Koch says foam sales are between $30 million and $50 million. That would give Ametek between one third to one half of what Kline & Co. estimates is a roughly $100 million foam sheet protective packaging market. Ametek does not break out division profits either. Net income for the company's 15 divisions was $37.3 million on sales of $661 million in 1990.

Ametek is the only U.S. and worldwide producer of low-density polypropylene foam sheet, according to Koch. The foam is produced via a proprietary flash extrusion process that Du Pont developed but sold to Ametek in 1983 to raise cash after its purchase of Conoco, he says. Production is rapid: At speeds approaching those of paper production, the foam is formed into a continuous sheet at Du Pont's original plant in Wurtland, Ky., and a newer plant in Fresno, Calif. A third plant is under construction in northwest Maryland, he adds.

Packaging sheet foam competitors include low-density polyethylene foam sheet and plastic bubble wrap producers. AVI Corp., Glens Falls, N.Y., and Sealed Air Corp., Saddle Brook, N.J., manufacture both types of plastic packaging. Other packaging competitors include manufacturers of macerated paper pads, cellulose wadding, and a type of corrugated cardboard with one smooth side.

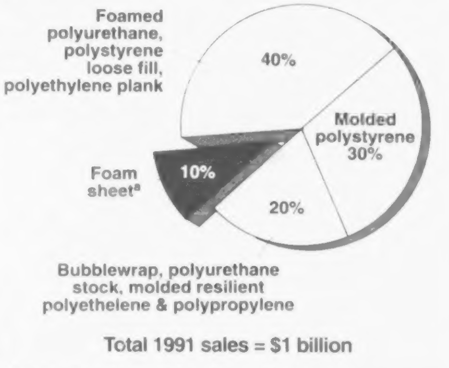
An Arco Chemical joint venture with Japan Styrene Paper and Mitsubishi Gas Chemical produces expanded polypropylene foam beads in the U.S. for sale to packaging manufacturers. However, Amoco and its partners do not sell a sheet foam. A manufacturer molds the beads into appropriate shipping packages. Ametek's closest plastic packaging competition, polyethylene foam, has a density of 1.2 lb per cu ft compared with 0.6 lb per cu ft for polypropylene foam. Koch says the low-density Ametek foam reduces the amount of polymer necessary to manufacture a cubic foot of foam, which ultimately means less waste should the material be discarded. If the polypropylene foam must be discarded, Koch says it would make more sense to incinerate it because it is "a good source for energy."

But a new shipping container, which the company refers to as a "couch pouch," will encourage reuse as well as recycling, says Koch. The couch pouch is a composite of polypropylene sheet foam and nonwoven polypropylene fabric that Ametek produces in eight sizes to enclose furniture. He says they may be reused five times or more, only cost 15% more than one-use paper bags, and weigh 75% less than paper.

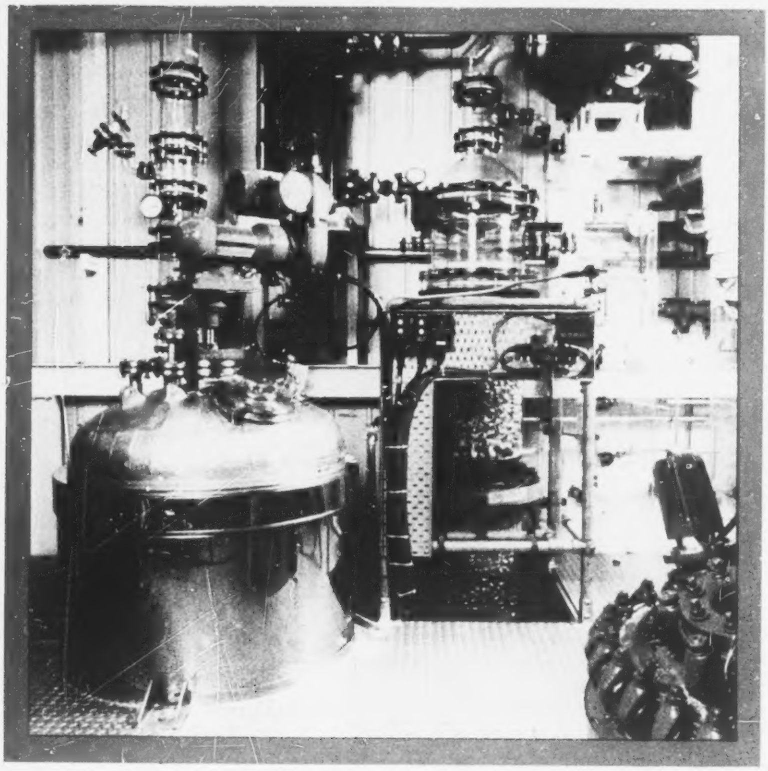
Other polypropylene foam uses the company is working on for its sheet foams include packaging for fruits such as apples and pears. Among small but developing markets are use as concrete curing blankets in place of glass fiber, insulation for greenhouse knee walls, and underlayment for flat asphalt roofing systems. It also may find use in oil-spill containment curtains because of the foam's buoyancy, flexibility, light weight, and ability to absorb light oils.

Marc Reisch

Foam sheet is now only 10% of protective plastics packaging market



a Polyethylene and polypropylene. **Source:** Kline & Co.



Stainless steel reactor at Newport Pharmaceuticals Ireland can handle reactions carried out at –100 °C

Custom Chemical Producers Set to Meet Industry Changes

Stephen C. Stinson,
C&EN Northeast News Bureau

Widespread changes rippling through the fine chemicals industry have also had an impact on the business of custom chemical production within that industry.

Among these changes are a wave of consolidations through mergers and acquisitions; a trend to more complex molecules tailored to customer needs; greater willingness even by large firms to seek outside sources of chemicals; stricter requirements for chemical product quality; and tightening regulations on pollution, waste disposal, and safe production and transportation.

As a result, the fine chemicals industry and its custom production segment must adopt several production strategies to be successful in the next century, according to Enrico Polastro, fine and specialty chemicals director at Arthur D. Little International in Brussels. First, companies should establish a balance between the efficiency of single-purpose facilities and the flexibility of multipurpose facilities. Companies can use single-purpose units to produce a steady stream of standard catalog compounds to balance out their custom production on the multipurpose equipment.

Second, Polastro says, companies must participate in the consolidation of the industry to attain the minimum size needed for survival. A minimum size is needed to justify the investment in production safety, pollution abatement, and waste disposal. He suggests this size is $50 million per year in sales.

And third, companies must avoid obsolescence of technologies and equipment in an age of rapid evolution of types of chemicals demanded. They must create a balanced portfolio of production technologies, including key technologies not widely available that turn out high-value-added products.

Sales of the world fine chemicals industry are about $45 billion per year, estimates Zack I. Levine, vice president and general manager of the Hoechst Celanese fine chemicals division. Of this, 50% is drugs, 20% is pesticides, 5% is aroma chemicals, 5% is food additives, and 20% is "other," which includes high-performance polymers, monomers, and plastics additives, reprographic chemicals and photoresists, and colorants. The U.S. market is $15 billion, he says, and is growing at about twice the gross national product.

How much of this is custom production is hard to estimate. Much custom work is one firm making a unique compound for one client with the compound's value shrouded under secrecy agreements. And some large companies that do custom work on the side only do so to use spare kettle space. Analysts at Kline & Co., Fairfield, N.J., have put U.S. custom production at $1.7 billion per year.

Levine cites a shift toward greater molecular complexity as an opportunity for fine chemicals makers. Especially in the drug industry, molecules are more highly designed to perform a predetermined function. As Levine puts it, "All of the simple molecules have been discovered."

Because of greater targeted effectiveness, smaller volumes of fine chemicals production will be needed. The opportunity here is that supplier firms can increase versatility and responsiveness as their clients grow reluctant to produce small volumes themselves. But as competition grows among end users of fine chemicals to design for the same disease or functional property, the life cycle of any one fine chemical will be shortened. "This could present a real

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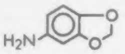
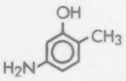
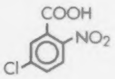
3,4-Methylenedioxyaniline and N-Ethyl derivative



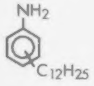
5-Amino-o-cresol



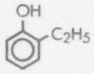
5-Chloro-2-nitrobenzoic acid



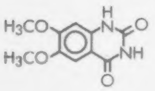
Dodecylaniline
(isomer mixture)



2-Ethylphenol



6,7-Dimethoxyquinazoline-2,4-dione



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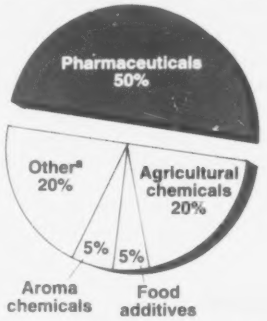
Pharmaceuticals account for half of fine chemicals sales



1991 worldwide fine chemicals sales = $45 billion

a Includes plastics, monomers, and additives; reprographic chemicals and photoresists; and colorants. **Source:** Hoechst Celanese

opportunity for smaller, more rapidly moving organizations and a major obstacle for large, more highly structured organizations," Levine says.

In another area, that of consolidation and growth by acquisition, two of the most active companies in the U.S. have been Cambrex Corp., Bayonne, N.J., and MTM of Cleveland, England.

Cambrex came into being when NL Industries spun off its Baker Castor Oil Co. as an independent in 1981. Since then, the company has acquired Cosan Chemical Corp. (1985), Nepera (1986), Heico Chemical and Humphrey Chemical Co. (both 1989), and Salisbury Chemicals (1991). Cambrex is currently negotiating with Hexcel Corp. to acquire that company's chemical products division. Combined sales from all sources were almost $140 million in 1990.

Though all these components are far flung, the custom synthesis business for all of them is handled by Stuart Needleman at the Cambrex plant in Carlstadt, N.J. He prospects for new custom business, and subsidiaries refer any inquiries to him. Needleman sits on committees of each subsidiary to evaluate new proposals for profitability and environmental concerns.

In keeping with Polastro's call for key technologies not widely available, Needleman can offer nitration, metal reductions in liquid ammonia, high-pressure hydrogenation, and chemistry involving mercury and arsenic. As Needleman quips, "We're looking for

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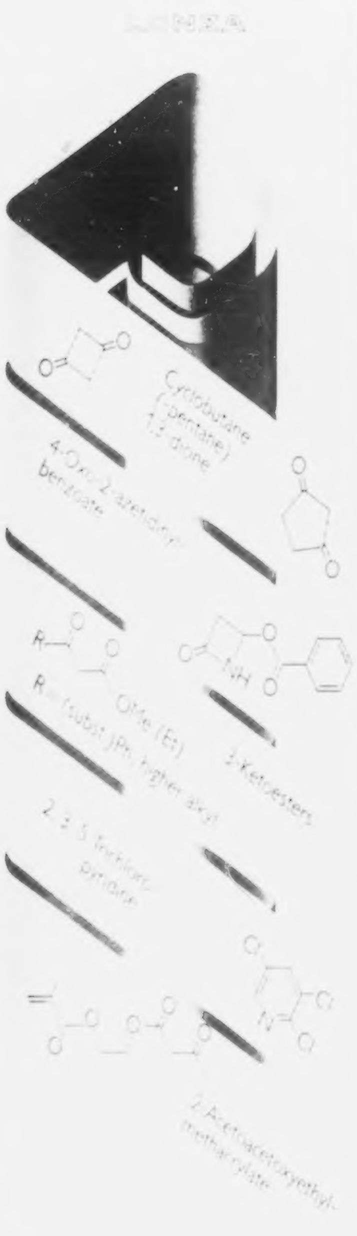
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R
OMe (Et)
R = (subst.)Ph, higher alkyl
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2,3,5-Trichloropyridine
Cl
N
2-Acetoacetoxyethyl methacrylate

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situations in which we have an unfair advantage over the competition."

In particular, nitration is a dangerous process itself, and the resulting nitro compound also may be explosive. So rather than take delivery of a nitro intermediate, customers may prefer to let Cambrex proceed with a reduction process. The upshot may be that Cambrex gets to do all of a multistep synthesis because of the nitration and reduction in the middle.

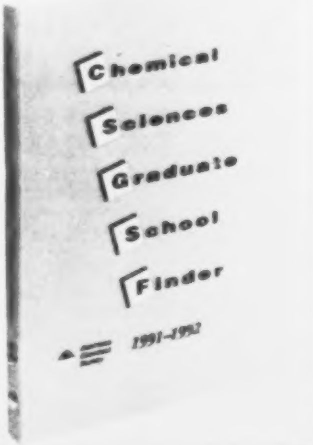
Chemistries of the Cambrex subsidiaries are complementary too, so integration among them is possible. Says Needleman, "We have one ongoing project where Humphrey makes the starting material, Heico does the next step, and Salisbury does the finishing step."

Acquisitions also have been a spur to growth during MTM's move into the U.S. The company began with a sales office in Houston in 1983. In 1988 MTM bought Fairfield Chemical Co. and Draybor. And in 1990, MTM Chemical got the Orsynex subsidiary of Essex Chemical Corp. after Dow Chemical USA acquired Essex in 1988. Farchan Laboratories, Monomer Polymer Corp., and Hardwicke Chemical Co. also were bought in 1990.

Though the company has many subsidiaries organized under the two umbrellas MTM Chemicals and MTM Research Chemicals, executive vice president John Luvisi is the contact for custom production. Luvisi, who is with MTM in Charlotte, N.C., can arrange business within MTM according to the quantities needed, the chemistries required, and whether the customer needs a Food & Drug Administration-approved plant.

In other activity, Outokumpu Metals & Resources of Helsinki, Finland, formed a new company, OM Group, Cleveland, Ohio, in 1991, which acquired Mooney Chemicals of Cleveland; Outokumpu Chemicals of Kokkola, Finland; and Vasset of Ezanville, France. OM Group makes a standard line of metal carboxylates and also produces such compounds to order.

Burnham Tinker, vice president for research and development, says the OM Group has technology to make metal carboxylates of high batch-to-batch consistency and free of impurities like sodium that enter as a result of traditional methods of metathesis (double decomposition). The company's oil-



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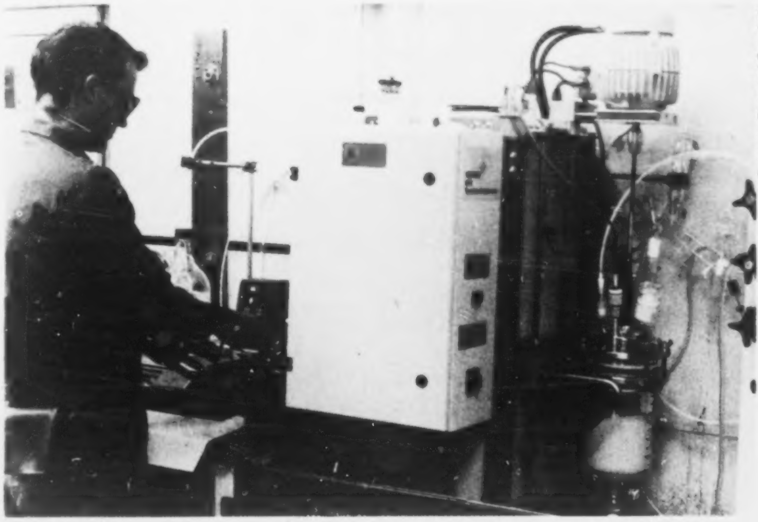
soluble or water-dispersible metal carboxylates find uses as coatings; rubber, plastics, and lubricant additives; and as homogeneous catalysts. They also are precursors of heterogeneous metal catalysts on mineral supports.

Affiliation with Outokumpu also brings technology to OM Group allowing it to make such inorganic salts as chlorides, nitrates, and sulfates, Tinker says. But more important than technology, the new firm offers technical support and reliability of supply of cobalt and nickel. The price and supply of these metals fluctuate frequently.

Sigma-Aldrich Corp., Milwaukee, bought Fluka Chemie of Buchs, Switzerland, and Ronkonkoma, N.Y., in 1989. Like Sigma-Aldrich, Fluka supplies laboratory reagent chemicals and bulk chemicals as catalog items or produced to order. The Milwaukee concern has set up a marketing organization called SAF to sell bulk chemicals and custom production services.

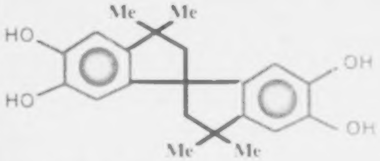
Clint Lane, executive vice president, says one forte of the company is production of enantiomeric compounds. These are available by asymmetric syntheses with *B*-chlorodiisopinocampheylborane or through resolutions of racemic mixtures. And the Sigma Chemical Co. subsidiary in St. Louis offers custom synthesis of biochemicals, mostly radiolabeled compounds.



Eastman Chemical Co. photo

Technician runs design experiment prior to scaleup of a custom chemical project

Another recent acquisition was SmithKline Beecham's fine chemicals plant in Conshohocken, Pa., by Lonza of Fairfield, N.J., in 1991. Raimund J. Miller, who is director of commercial development, says the new plant will expand Lonza's ability to offer custom production in the U.S., as will a



Photographic Image Stabilizer
JP 02286642 (1989)

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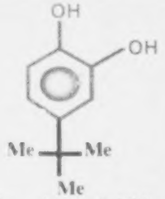
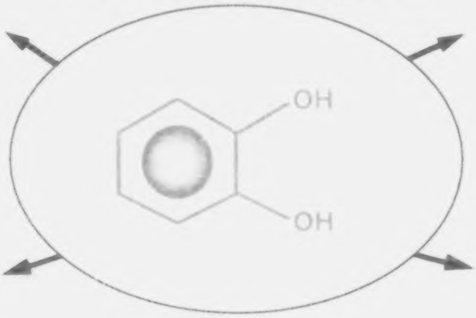
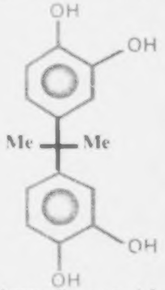
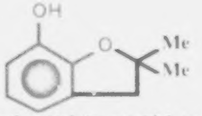
The Versatile Raw Material



Polymerization Inhibitor
JP 02152939 (1990)







Agrochemical (insecticidal) intermediate
U.S. 4639536 (1987)

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JP 02185491 (1989)

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planned expansion of the Lonza plant in Bayport, Tex.

Like so many firms successful in custom production, Lonza is skilled in handling dangerous substances. The company already makes diketene in Texas, and will bring its overseas technology for hydrogen cyanide and chlorosulfonyl isocyanate there as well. These chemistries are currently practiced at the plant of the parent company in Basle, Switzerland. There Lonza uses hydrogen cyanide to make malononitrile, which is used to produce triamterene to treat high blood pressure, and to make aminopyridines for herbicides. Chlorosulfonyl isocyanate is used to introduce carboxamide groups into drug molecules.

Indeed, syntheses involving diketene will have to be custom-ordered. Lonza and Eastman Chemical, the other producer, have decided to stop shipping the intermediate because of the potential for accident with the explosive, acid-sensitive material.

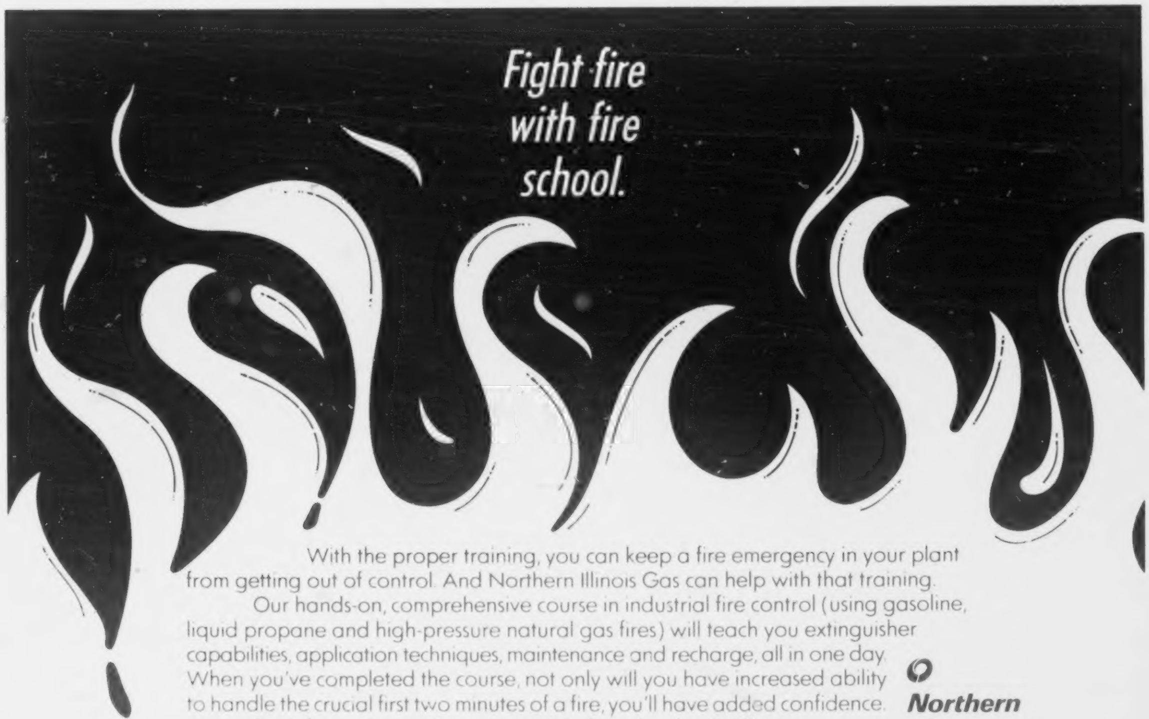
Another company with a European parent, Hüls America of Piscataway, N.J., also has garnered new custom production capabilities by acquisition. In 1987, the German parent bought the chemicals and plastics business of Dynamit Nobel; the acquisition resulted in the merger of Dynamit Nobel of America with the New Jersey firm. This merger spawned the organic chemicals producer Kay-Fries, and Petrarch, which makes organosilicon compounds.

The U.S. manager for custom production at Hüls America is Robert J. Morlino, who is vice president for intermediates and specialty chemicals. Whether the company fills a custom order from the U.S. or Germany depends on clients' desires and where the needed chemistries or equipment is avail-

Companies must balance efficiency of single-purpose equipment with flexibility of multipurpose equipment

	Single-purpose equipment		Multipurpose equipment
	Single product	Multiproduct	Multiproduct
Operation	Continuous	Continuous or batch	Batch
Advantage	Efficiency	Efficiency and some flexibility	Flexibility
Applications	Large-volume standard intermediates and bulk actives	Small-volume standard intermediates	Small-volume bulk actives and custom synthesis

Source: Arthur D. Little Inc.



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able. Morlino says he exchanges a monthly "sorry" list with his counterpart in Marl, Germany. This list describes queries that either person has had to decline in the past month but that the other may see as an opportunity.

In a change of direction elsewhere, Reilly Industries, Indianapolis, is moving away from custom manufacture, but bought Morflex of Greensboro, N.C., which does do custom manufacture. Acquired in 1990, Morflex offers a variety of chemistries and specializes in esters of polyfunctional acids. Though esterification may seem straightforward, Lee Skinkle, director of sales and marketing, says the firm's strength is in its ability to work with high, medium, and low molecular weight acids and alcohols and to process esters in liquid or solid form.

Like so many companies in custom production, Morflex has found a niche by doing some reactions but not others. The company does not do nitration or hydrogenation, for example, but has reliable sources to subcontract such chemistry. As Skinkle puts it, "The custom manufacturing industry is its own very important customer."

Just as Morflex has branched into other areas of custom production based on ester technology, so Pfanstiehl Laboratories, Waukegan, Ill., has capitalized on its expertise in sugar chemistry. Pfanstiehl president A. George Holstein says this capability has brought the company to the attention of customers wanting a custom supplier with a plant that is approved by FDA and that follows so-called good manufacturing practices. And the firm has applied techniques for sugar chemistry to such analogous problems as isolation of botanical products. In some of its work with sugars, Pfanstiehl makes the anticancer drug cytarabine, the 1-acetyl-2,3,5-tri-*O*-benzoyl-D-ribofuranose precursor to antiviral ribavirin, and the glucose-derived antipsoriasis agent amiprilose.

Custom synthesis has unique role in fine chemicals production

	Fine chemicals		
	Standard intermediate	Standard bulk actives[a]	Custom synthesis
Range of structures	Very broad	Very broad	Few
Applications of compounds	Several	Single	Single
Life cycle of compounds	Long	Short	Unpredictable
Basis of competition	Price	Price	Flexibility
Impact of raw material costs	High (> 60%)	Highly variable	Limited (< 40%)

a Generic drugs, pesticides, and electronic chemicals. **Source:** Arthur D. Little Inc.

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Another company with a differentiating specialty is Sepracor, Marlborough, Mass. Steve Brandt, director of marketing, says his firm custom-produces enantiomeric compounds by diastereoisomeric fractional crystallization, biocatalytic kinetic resolution, and asymmetric synthesis.

Diastereoisomeric resolution is the classical method that makes use of salts of racemic acids with, for example, enantiomeric α-phenylethylamine or racemic bases with enantiomeric tartaric acid, which are fractionally crystallized to resolve the substrate.

In biocatalytic kinetic resolution, an enzyme preferentially hydrolyzes one enantiomeric ester or amide in a racemic mixture. Sepracor has devised hollow-fiber membrane bioreactors for kinetic resolution in which the membrane material bears an immobilized enzyme.

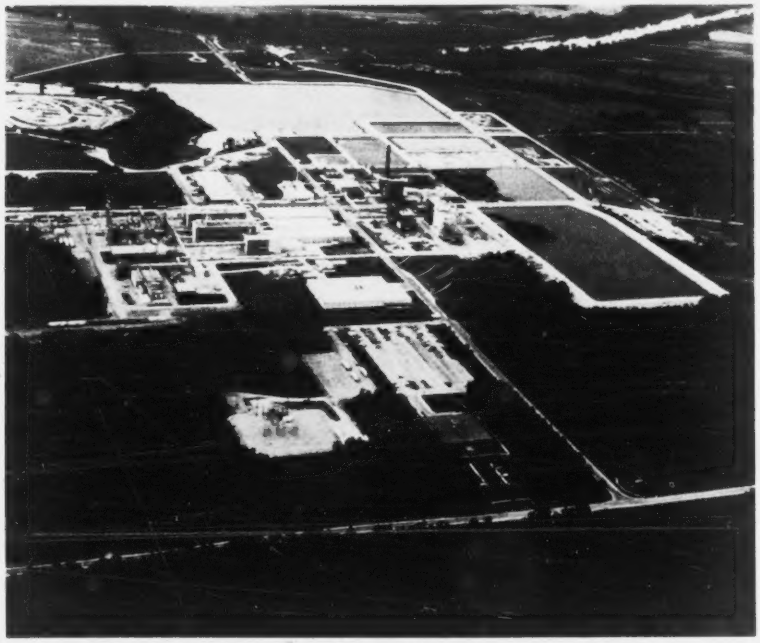
[illegible] version, an organic solution of racemic glycidyl butyrate flows along one side of a membrane bearing immobilized pig pancreatic lipase. An aqueous phase flows along the other. The lipase hydrolyzes (*R*)-glycidyl butyrate preferentially. (*R*)-Glycidyl alcohol passes through the membrane and is carried away for collection in the aqueous phase. Brandt says that potential production in the company's commercial-scale modules is 100,000 kg per year.

For asymmetric syntheses, Sepracor has licensed the catalytic asymmetric dihydroxylation of olefins developed by organic chemistry professor K. Barry Sharpless, who is now at Scripps Clinic Research Institute, La Jolla, Calif. (C&EN, July 22, 1991, page 19).

For some types of expertise, U.S. clients for custom chemical production have found it not only possible but necessary to go overseas. For example, Lonza's Miller says his firm specializes in ozonolysis at its plant in Basle, Switzerland. Few companies do ozonolysis in the U.S.

Mary Collins, manager of process development at Newport Pharmaceuticals Ireland in Dublin, described her company's facilities for carrying out reactions down to −100 °C to the Chemical Specialties buyer-supplier symposium in Cherry Hill, N.J., last October. The advantages of very low temperatures are reaction selectivity and stereoselectivity in asymmetric syntheses, Collins said.

The low-temperature reactor at



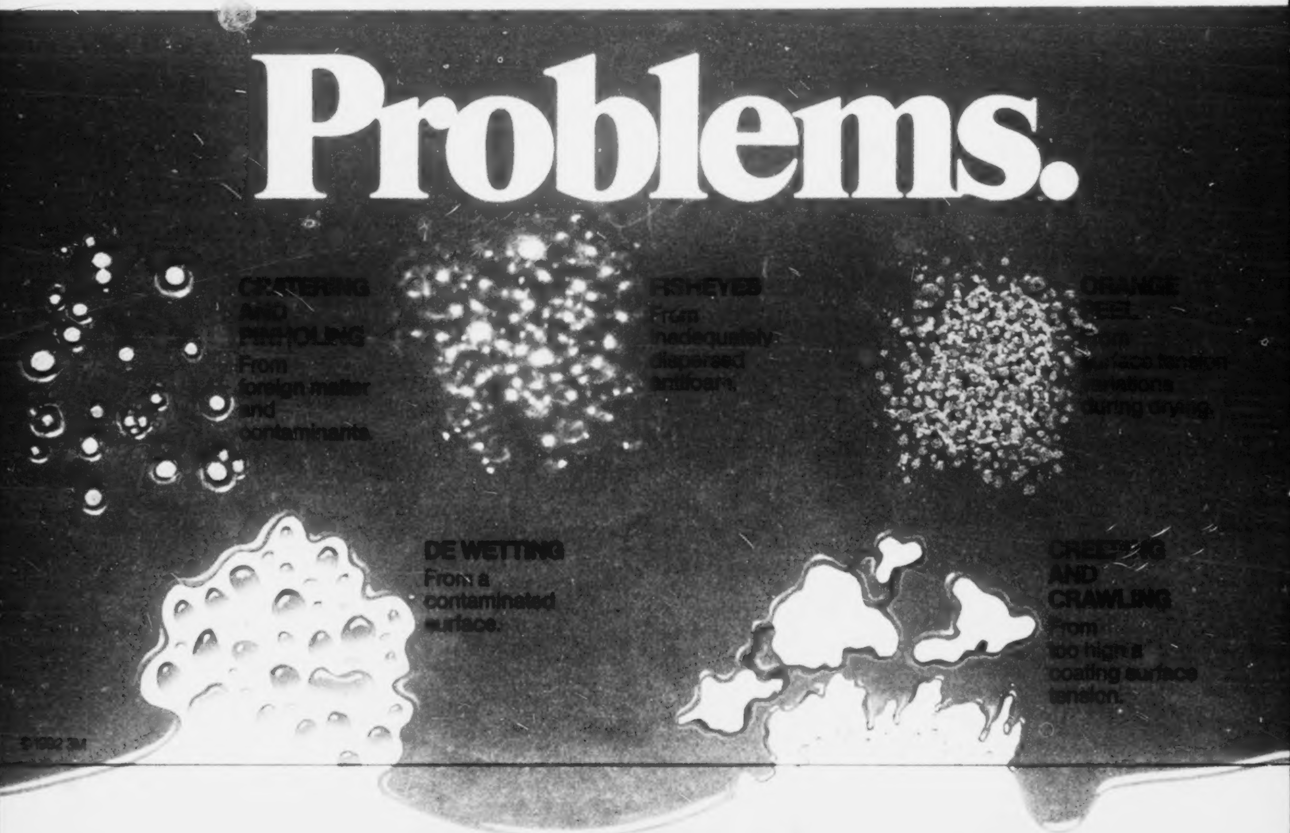
Eastman Chemical's custom chemical facility in Batesville, Ark.

What custom production entails

Custom chemical production is the synthesis of organic or inorganic compounds according to a buyer's special order. These compounds may be intermediates that are unavailable from the catalogs of any company in the fine chemicals industry (standard intermediates). Or they may be finished end products originally discovered in customers' research (bulk actives). Other aspects of the total custom chemical manufacturing industry include such physical processes as drying, grinding, or distillation.

A subset of custom production is toll manufacture. This occurs when a customer ships a raw material to the

Newport is chilled by circulating methanol, which is brought to the proper temperature by circulation with liquid nitrogen through a heat exchanger. In one synthesis the company does, a re-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custom producer to carry out one or more synthetic steps before getting the product back.

Some companies order custom production because they have no spare pilot plant or large-scale capacity of their own. Many firms wait until a product is a proven marketing success before building capacity for it. And in the current recession, companies that might otherwise build or expand their own capacity postpone investment until better times.

Custom production is also ordered when it involves unfamiliar chemistry—for example, synthesis of an inorganic catalyst for the process of an organic chemicals producer. Dangerous reactions such as nitration, high-pressure hydrogenation, or phosgenation might be farmed out, especially by firms whose own plants are in populated areas.

Analyst Enrico Polastro of Arthur D. Little International, Brussels, outlined the characteristics of chemical production within the fine chemicals industry in a presentation to the Chemical Specialties convention last October in Cherry Hill, N.J.

First, he said, custom chemicals have an unpredictable life cycle. This is because a client's product may fail in the market, a drug may show toxic side effects, or a customer may take production in-house. And a custom compound has only one use—that of the customer—compared with standard intermediates that are precursors to several compounds.

Second, in contrast to standard intermediates or bulk actives, delivered price plays a small role in whether the custom producer gets the business. Custom producers compete on the basis of flexibility and rapidity of response.

Third, because most of custom production cost is in process development and time in special equipment, raw materials cost is less than 40% of delivered price, compared with more than 60% for standard intermediates or bulk actives.

actant must be added over a period of 10 hours to a stainless steel reactor chilled precisely to −65 °C the whole time

Collins estimated this step adds $1850 per kg-mole to the cost of the final product, which would be $12.33 per kg for a molecular weight of 150. This cost may seem high, yet the same reaction carried out conventionally at 0 °C would produce only half the yield, require much longer workup time, and have to be carried out in a glass-lined vessel.

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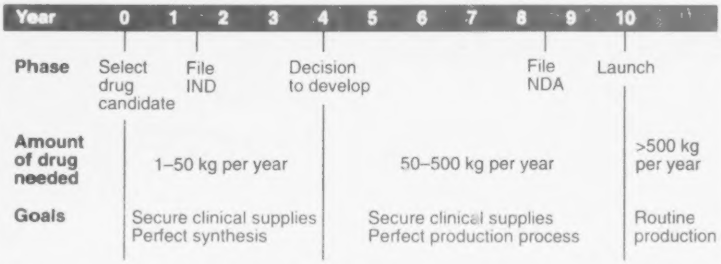
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1
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10
Phase
Select drug candidate
File IND
Decision to develop
File NDA
Launch
Amount of drug needed
1–50 kg per year
50–500 kg per year
>500 kg per year
Goals
Secure clinical supplies
Perfect synthesis
Secure clinical supplies
Perfect production process
Routine production

IND = Investigational new drug. NDA = New drug application. **Source:** Hoffmann-La Roche

ranged when customer and custom producer meet, is most often arranged through the client's purchasing agent, says Morlino of Hüls America. His experiences are probably representative of custom producers meeting business prospects.

Purchasing agents for custom production customers are usually associated with research, specialize in buying custom production, and have degrees in chemistry, as do Hüls' salespeople. Typically, salespeople want to expand their contacts by getting beyond the purchasing agent to persons in research or production. And also typically, purchasing agents don't want to allow this. They fear losing control of orderly contracting. And the purchasing agent may be the only one who knows what information may be given to the prospective vendor.

Like so many vendor companies that have expanded by acquisition, Hüls tries to keep a small-company atmosphere and avoid bureaucracy. This is hard, Morlino says, because increasingly stringent regulations on safety, pollution, and waste disposal require centralized management. In addition, customers now often ask to see that Hüls has written policies and procedures and follows these.

Part of avoiding bureaucracy is the ability to sign secrecy agreements quickly. Morlino says Hüls has streamlined this legal process, and that secrecy agreements are easier now. He recalls that 10 years ago, a customer might demand in the agreement that the vendor return any paperwork associated with the contract on demand. But after much paperwork over many years, it might be impossible to guarantee complete compliance.

Also like other vendors, Hüls takes the risk that the customer's end prod-

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MAKING THINGS WORK

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uct may fail, or that it will succeed and the customer will take production in-house. In such a case, the vendor may lose all the money spent on process development after delivery of only a small amount of product.

Morlino acknowledges that most custom production contracts are worthless, because the customer will ask to be let out according to business exigencies. And Hüls may agree to cancellation to keep up a long-term relationship. Contracts exist, then, mostly to please managements.

If this is the way things often appear to a vendor, John W. Scott described one customer's view to the Chemical Specialties symposium in October. Scott is director of chemical development at Hoffmann-La Roche, Nutley,

Conventions key to custom chemical producers

Two conventions have become established in the U.S. to introduce buyers of custom chemical production to services and firms that might supply them. The seventh annual meeting of Informex will be in New Orleans, from Feb. 17 to 19. And the third annual meeting of Chemical Specialties symposium and exposition will take place from Oct. 5 to 8 in Cherry Hill, N.J.

Informex, which is sponsored by the Synthetic Organic Chemical Manufacturers Association (SOCMA), is the only convention solely dedicated to concerns of custom production. The meeting will begin on a Monday at the Fairmont Hotel with registration and an evening reception. The several hundred attendees who are expected will have the next two days to tour an exposition of about 120 firms that offer custom chemical synthesis and/or physical processing.

In addition, Tuesday will feature panel discussions on environmental and waste disposal issues, plus a plenary paper by analyst Ernest Gilmont of Arthur D. Little Inc. on competitive intelligence. Moderated by Cable Network News reporter Marc Levinson, the environmental issues panel will include actor and environmental activist Ed Begley Jr., and Rob McCord of the Congressional Institute of the Future. The waste disposal issues panel will consist of Art Gillen of BASF Corp., Jim Norris of BCM Engineering, and Jim Bratina of Reilly Industries.

Chemical Specialties USA '92, which is organized by Spring Innovations of Stockport, England, is more generally concerned with specialty chemicals, but includes papers and exhibits dealing with custom production. This meeting also will begin with registration late on a Monday, at the Hyatt Cherry Hill Hotel. About 1000 persons are expected to register. The affair will consist of a symposium, an exposition, and sessions of meet-the-supplier seminars called Specmart.

The symposium program has not yet been finalized, but plans call for it to begin on Tuesday with about 20 papers spread out over two mornings and an afternoon. Speakers will represent custom chemical service firms, their clients, and consultants who follow this segment of industry.

The exposition opens Wednesday and will run two full days. About 100 exhibitors are expected. On Wednesday afternoon and Thursday morning, attendees can drop in on small Specmart seminars by selected supplier firms.

Those interested in attending Informex should contact Amanda Frederick of SOCMA, 1330 Connecticut Ave., N.W., Suite 300, Washington, D.C. 20036, fax (202) 659-1699.

Those in North America who wish to attend Chemical Specialties USA '92 should contact the U.S. representative, Brandon Associates, P.O. Box 1244, Merrimack, N.H. 03054, telephone and fax (603) 424-2035.

N.J. Fine chemicals companies that want to supply Roche must deal with greater complexity of synthesis, increasing attention to FDA for validation and statistical process control of production, and Roche's constant striving to improve quality.

As to complexity, Scott notes that new drugs under development at his firm require 12 to 23 chemical steps. For those that are chiral, Roche has adopted a policy of developing only one enantiomer, which adds to complexity. Overall yields of active bulk compounds can be less than 5%. Because Roche is located in a densely populated New York suburb, vendor firms have the opportunity to supply the company with custom production based on dangerous reactions and reactants.

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As to FDA's closer attention to processes, suppliers will have to work with Roche in thorough studies of each chemical step and put the steps under statistical process control. And suppliers to Roche must upgrade quality to Roche's own standards in order to eliminate problems in processes that involve rework even after commercial production has begun.

As Roche's drugs move through development, amounts needed increase and production philosophy changes. For the first four years after selection of a drug candidate, annual needs are only 1 to 50 kg. The emphasis is on getting enough for clinical studies with little attention paid to synthesis or costs.

About the fourth year, the firm decides on full development. At this moment, needs rise to from 50 to 500 kg per year, and emphasis changes from synthesis to process. As to potential suppliers to Roche, Scott distinguishes among "kilo labs," fine chemicals manufacturers, and other drug firms.

Directories help buyers locate sellers

People seeking custom chemical production can find providers of such services in several published sources. The Custom Chemicals Directory section of the American Chemical Society's "Chemcyclopedia" lists providers alphabetically with addresses, telephone numbers, and capsule summaries of the expertise of each. The current 1992 edition costs $60.

Brandon Associates, Merrimack, N.H., publishes "The Brandon Guide to Custom Chemical Synthesis Services—North America" at $170 for the 1991 edition. The price includes two semiannual updates. The book gives one-page entries for more than 300 firms, cross-indexed according to 200 processes. The one-page entries include equipment and processes available, details of pollution control, waste handling, and analytical instruments, and whether the plant is approved by the Food & Drug Administration.

Custom Guide Co., Closter, N.J., puts out a "Custom Processing Services Guide" at $300 for the 1990 edition, including two semiannual updates. The book gives one-page entries for almost 400 companies, listed by plant locations and cross-indexed according to processes. The format is designed for users without purchasing agent experience, who can compile a list according to capabilities and then limit it to those plants nearby for visits. The one-page entries include equipment and processes available.

Delphi Marketing Services, New York, N.Y., will publish the 1992 edition of its "Directory of Custom Chemical Manufacturers" in February, priced at $260. The one-page entries for almost 300 firms include equipment, unit operations, and reactions available, whether there is general and product liability insurance and a person designated for regulatory affairs,

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CIRCLE 30 ON READER SERVICE CARD

and whether the plant is FDA-approved.

Also in February, Quest Data, Nashville, Tenn., will put out a new edition of "A Guide to Custom Chemical Manufacturing & Processing"; the group expects to price the publication at about $150. Three semiannual updates are included in the price. More than 500 companies are listed. In addition to equipment and processes available, a full slate of chemicals regularly produced is given. Entries include provisions for pollution control and waste disposal, analytical instruments available, and whether the plant is FDA-approved.

For buyers of custom chemical production who don't want to pore over directories or keep up their own files, brokers provide an attractive alternative. One such broker is Jonas Chemical Corp., Brooklyn, N.Y. Jonas doesn't produce any custom chemicals itself but can suggest where to get things done.

Kilo labs are small companies that generally produce in 22-L glass flasks. Though their flexibility is good and their staff quality high, they are not large enough to carry out the type of development program needed in the new industrial climate.

Other drug companies and their wholly owned custom production subsidiaries are fully able to meet evolving requirements for development and are thus potential suppliers to Roche. But there are worries in cases where the other drug company has drugs in classes similar to those of Roche. That leaves the larger fine chemicals suppliers, who will reap tremendous opportunities provided they can keep adjusting to evolving requirements.

Although drug companies are the largest dollar market for custom chemical production, chemical and plastics companies buy the most diverse kinds of products. At Dow's Michigan division, Joseph Raab is a purchasing agent for chemical raw materials. And at Monsanto Chemical Co., Edward Moore is manager of toll manufacture and custom synthesis. Both are longtime veterans of research and production at their companies, each with 15 years in purchasing alone.

In his constant search for potential suppliers of custom production, Dow's Raab uses SRI International's "Directo-

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Worker monitors custom chemical production at plant in Sterling, England

Eastman Chemical Co. photo

ry of Chemical Producers," the CIS "Directory of World Chemical Producers," and Chem Sources. Scott maintains his own file of companies and finds that trade shows such as Informex are useful.

Moore of Monsanto keeps his own computerized file of suppliers, cross-indexed according to 20 kinds of equipment, 20 chemistries available, and geography. Such computer systems are available to buy, he says. Moore also makes contacts at Informex. Moore makes only limited use of brokers, whereas Raab uses them sometimes to find candidates that do not have their own sales organizations.

Both men are concerned that the custom suppliers have responsible approaches to safety and the environment. This is because both seek long-term relationships, uninterrupted by regulatory shutdowns or accidents, and want to avoid third-party liability. But, also as Raab puts it, "We want to be sure they have the same values as Dow." And Moore says, "We look at the vendor as a part of Monsanto."

In one anecdote about approaches to keeping long-term relationships, Raab says recently his company had to cancel a project that had been let out to three custom contractors. These contractors feared they would be "left holding the bag" on costs they had incurred. But Dow renegotiated expenses with them to "make them whole."

Each man has counterparts in other regions of the world who can order technologies there that are not widely available in the U.S. Raab notes that European firms are expert in ozonolysis, and Japanese companies are good with amino acid derivatives. ☐

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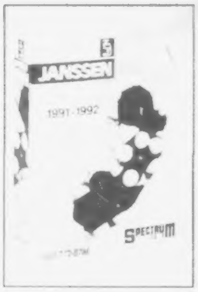

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CHEMICAL & ENGINEERING NEWS

C&EN

FEBRUARY 10, 1992

RESEARCHERS PUZZLE OVER SOURCE, ROLE OF ATMOSPHERIC METHANE PAGE 26

FEDERAL R&D FUNDING

Bush proposes 5% rise for 1993 despite otherwise very tight budget Page 7

CHEMICAL & ENGINEERING NEWS
C&EN
FEBRUARY 10, 1992

NEWS OF THE WEEK

- Severe ozone depletion likely will occur over far northern regions within the next decade, and reactions on sulfate aerosol particles are reducing rate of recovery from ozone loss. **Page 4**
- DNA oligomers used to block thrombin, an important enzyme in blood clotting, may lead to new group of therapeutic drugs. **Page 5**
- A district court has issued a permanent injunction to stop the Department of Energy from starting tests on an underground nuclear waste repository in New Mexico. **Page 5**
- New program, called TRANSCAER, is designed to help communities respond to spills and accidents involving transportation of hazardous chemicals. **Page 6**

COVER: Illustration by John Heinly

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ISSN 0009-2347

BUSINESS

Taiwan's petrochemical industry is shifting its focus to intermediates, prompting the building of new naphtha crackers and optimization of intermediates mix. **Page 17**

Trading in pollution rights draws closer to reality with the Chicago Board of Trade becoming the first exchange to propose to operate Environmental Protection Agency's sulfur dioxide emission rights sales program. **Page 19**

U.S. biotechnology market will grow 16% per year over the next 10 years to more than $14.5 billion by the year 2002, according to market consultants. **Page 20**

GOVERNMENT

State Department's low commitment to science and technology is bemoaned in report by Carnegie Commission on Science, Technology & Government. **Page 23**

SCIENCE/TECHNOLOGY

Conference on atmospheric methane underscores difficulty of defining methane's role in global warming, presents new findings on other atmospheric gases. **Page 26**

Stable, versatile methyltrioxorhenium catalyst for olefin metathesis, olefin oxidation, and conversion of aldehydes to olefins has been developed in Germany. **Page 29**

NEWS FOCUS

BUDGET
OF THE
UNITED STATES
GOVERNMENT
FISCAL YEAR 1993

In the proposed 1993 budget the Administration recently sent to Congress, R&D funding would increase 5%, with individual investigators receiving more support but facilities getting less. Page 7

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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Describing hazardous substance

Some months ago you quoted in Newscripts a letter I wrote (C&EN, Sept. 30, 1991, page 84) proposing Conrail for the Euphemism of the Year award for describing butane as a "light, nontoxic hydrocarbon which is commonly used for cigarette lighter fuel." This prompted a letter (C&EN, Dec. 9, 1991, page 2) from Alex Perkins in which he defended Conrail and in which this surprising question appears: "Certainly, the Conrail spokesman could have referred to butane as highly flammable, but does that really serve a purpose?"

It certainly does. For example, on Dec. 23, 1991, a tankcar containing butane derailed and caught fire near Everett, Wash. According to an Associated Press report, the tankcar was still burning two days later, and 100 nearby residents were still evacuated from their homes.

I submit that in the description of a hazardous substance, the most important property should be listed first—not last.

Sidney Toby
Rutgers University
New Brunswick, N.J.

Organic compounds in glass

In David L. Morse's haste to debunk the uniqueness of trapping of organic molecules in porous sol-gel glasses (C&EN, Oct. 28, 1991, page 2), he blundered. Had he practiced his advice to examine the literature before making claims (there are some 150 papers on the sol-gel trapping technique and on its applications), he would have discovered that there is a world of difference between adsorption, impregnation, and surface derivatization on the one hand, and trapping of organic molecules and enzymes in polymerizing metal alkoxides on the other. The literature on the former is voluminous (much beyond Gafney et al. in 1983 and Borelli et al. in 1983, which Morse cites; as well as beyond his unreferenced mention of xerogel uses in the 1960s and of enzyme immobilizations); the latter was, to the best of our knowledge, first described by us in the *Journal of Physical Chemistry* [88, 5969 (1984)] and a year earlier in a patent application (Israel patent application 69794, Sept. 23, 1983). Perhaps most notable in that method is the unique combination of true cage-encapsulation, which still allows chemical reactivity with the environment—a development that led to new designs of chemical sensors, of (photo)catalysts, and of bioactive materials (C&EN, May 27, 1991, page 24).

It is true that luminescence of trapped organic molecules in glasses such as boric acid or lead-tin-fluorophosphate is known, yet one should recall that glasses like the ones obtained from boric acid are essentially similar to those obtained by freezing organic solvents, and therefore the comparison to the polymeric network obtained in the sol-gel process is not so straightforward. And we still believe that the present ability to take the thousands of years of history of simple classical silica glasses, and push it a substantial step forward via the sol-gel method, is an important development in modern materials science, with applications that are bound only by imagination.

David Avnir
Chairman, School of Chemistry
Hebrew University of Jerusalem

Cold fusion

Science sociologist Trevor Pinch's review of my book, "Fire from Ice: Searching for the Truth behind the Cold Fusion Furor" (C&EN, Jan. 13, page 28) offers some praise for my account, but evidences the same arrogant misunderstanding of cold fusion research made by my opposite, author Frank Close. Then, lumping both of us together, he fallaciously asserts that both books employ "unrealistic models of science."

Corrections

- Jan. 6, page 42: For the ACS Rubber Division Nashville meeting, four copies of a 200-word abstract must be mailed before May 1 to Julian M. Mitchell, c/o ACS Rubber Division, P.O. Box 499, Akron, Ohio 44309-0499.
- Jan. 13, page 36: The contact for the April 3–4 Two-Year College Chemistry Conference has been changed to O. H. Bezirjian, College of Marin, Kentfield, Calif. 94904.

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Bush's 1993 Budget Proposes 5% Increase in Funding for R&D

NSF's budget would exceed $3 billion, individual investigators would get more support, and various science education plans would receive more funding

David J. Hanson, Bette Hileman, Wil Lepkowski, Janice R. Long, and **Pamela S. Zurer,**
C&EN Washington

President Bush's budget proposal for fiscal 1993, submitted to Congress on Jan. 30, calls for increased spending on federal R&D activities, but the overall increase he is seeking isn't so large as in his two previous comprehensive budget proposals, primarily because of a scaleback in defense-related research activities.

Under the President's 1993 budget proposal, overall outlays to conduct R&D would be up 5%, or $3.1 billion over current levels, to $72.8 billion. Within that total, outlays for defense R&D, conducted by both the departments of Defense and Energy, would increase 4% to $41.6 billion. However, for civilian R&D outlays would rise 6% to $28.1 billion.

Funding for basic research follows the same pattern as conduct of R&D funding, with outlays for defense basic research slated to rise 8% to $1.3 billion and for civilian basic research 7% to $12.1 billion. The only thing not going up in the overall R&D budget is facilities funding, outlays for which would fall 3% to $3.2 billion.

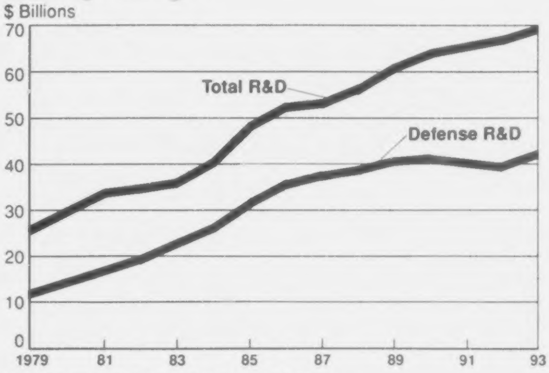
The fiscal 1993 budget proposal contains a number of new, or at least redefined, applied research initiatives. The Federal Coordinating Council for Science, Engineering & Technology (FCCSET), which operates under the auspices of the White House's Office of Science & Technology Policy (OSTP), took a look at two new areas this year. The council performs crosscut analyses of the research programs being carried out by various federal agencies in specific areas of science and technology and then develops coordinated national strategies for meeting long-range goals in those areas.

As a result, there is a new Presidential initiative in advanced materials and processing funded at a level of $1.8 billion, an increase of $162 million over current funding, and another in biotechnology research funded at $4.0 billion, an increase of $271 million. Continuing as Presidential science and technology initiatives under the coordinating council's umbrella are high-performance computing and communications, up $148 million to $803 million; global-change research, up $263 million to $1.4 billion; and mathematics and science education, up $147 million to $2.1 billion.

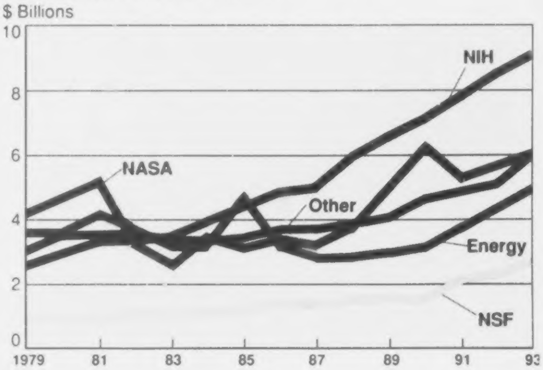
In the following sections, C&EN provides a closer look at the R&D budgets proposed for the various federal agencies that support research activities, starting with the largest R&D funding source.

Defense Department. The most unusual feature of this year's more than 1700-page budget book prepared by OMB that sets forth the facts and figures behind the fiscal 1993 budget is that the military functions of DOD are missing

Defense still accounts for 60% of federal R&D spending . . .



. . . while NIH gets lion's share of nondefense R&D funds



Note: Outlays. **Source:** Office of Management & Budget from the section that gives the nitty-gritty details on what is going to be spent where. The overall numbers are elsewhere in the book, however, and they show a declining budget for DOD under the President's proposal, mostly from cuts in big-ticket weapons programs and personnel.

A small decrease is also slated for DOD research spending. The fiscal 1993 request for defense research, development, testing, and evaluation programs (RDT&E) is $38.6 billion, 2% below the total fiscal 1992 appropriations. Of this total, according to DOD's own figures, it plans to spend $4.1 billion on basic and applied research, the so-called technology-base programs that are not tied to any specific weapons. This represents a 3% decrease from current-year spending, which is about even with fiscal 1991 spending.

This is the first time in recent memory that an Administration has requested such a decrease in technology-base research, and Congress is expected to come through with a bit more money. Under this category, DOD supports efforts in mathematics, chemistry, meteorology, biochemistry, and solid-state physics.

Under the much larger umbrella of development research programs, Defense plans to spend $34.4 billion. This category includes funding to bring advanced weapons systems to the production stage and to improve existing systems. Special emphasis will be on technology development efforts and the fabrication of prototype systems during the next year. The Administration has requested a large increase for the Strategic Defense Initiative (SDI), up to $5.4 billion from

Outlays for R&D are up 5% . . .

	Budget authority					Outlays				
$ Millions	1993 proposed[a]	1992 enacted[a]	1989 actual	% change 1992–93	% difference 1989–93	1993 proposed[a]	1992 enacted[a]	1989 actual	% change 1992–93	% difference 1989–93
BY AGENCY										
DOD	$40,509	$40,043	$38,031	1%	6%	$38,847	$37,175	$37,545	4%	3%
Health & Human Services	10,649	10,216	7,894	4	36	10,199	9,468	7,486	8	36
NASA	8,673	7,706	5,303	13	64	7,710	7,272	4,975	6	55
Energy	6,578	6,514	5,362	1	23	6,219	6,195	5,692	0	9
NSF	2,375	1,967	1,671	21	42	2,056	1,840	1,557	12	32
Agriculture	1,332	1,328	1,050	0	27	1,285	1,245	1,021	3	26
Commerce	614	580	417	6	47	582	542	363	7	60
Interior	552	583	467	−5	18	546	580	478	−6	14
EPA	525	496	389	6	35	495	454	345	9	43
Transportation	498	446	313	12	59	457	410	322	11	42
Other agencies	1,320	1,214	1,015	9	30	1,264	1,200	1,098	5	15
BY FUNCTION										
Conduct of R&D	73,623	71,093	61,913	4	19	69,658	66,381	60,881	5	14
Applied R&D	59,301	57,839	51,298	3	16	56,253	53,890	50,626	4	11
Defense[b]	41,988	41,582	39,678	1	6	40,295	38,758	39,596	4	2
Civilian	17,313	16,257	11,620	6	49	15,958	15,132	11,030	5	45
Basic research	14,322	13,254	10,615	8	35	13,405	12,491	10,255	7	31
Civilian	13,086	12,053	9,650	9	36	12,142	11,325	9,312	7	30
Defense[b]	1,236	1,201	965	3	28	1,263	1,166	943	8	34
R&D Facilities	2,933	3,498	2,293	−16	28	3,189	3,286	2,054	−3	0
TOTAL	$76,556	$74,591	$64,206	3%	19%	$72,847	$69,667	$62,935	5%	16%

. . . while those for basic research are up 7%

	Budget authority					Outlays				
$ Millions	1993 proposed[a]	1992 enacted[a]	1989 actual	% change 1992–93	% difference 1989–93	1993 proposed[a]	1992 enacted[a]	1989 actual	% change 1992–93	% difference 1989–93
Health & Human Services	$ 5,800	$ 5,459	$ 4,413	6%	31%	$ 5,541	$ 5,143	$ 4,234	8%	31%
NIH	5,328	5,019	4,052	6	31	5,109	4,748	3,988	8	28
NSF	2,221	1,839	1,563	21	42	1,917	1,730	1,455	11	32
NASA	2,068	1,860	1,385	11	49	1,851	1,715	1,346	8	38
Energy	1,859	1,789	1,383	4	34	1,771	1,695	1,377	4	29
DOD	1,203	1,170	951	3	26	1,230	1,134	929	8	32
Agriculture	639	611	486	5	31	589	576	477	2	23
Other agencies	532	526	434	1	23	505	498	438	1	16
TOTAL	$14,322	$13,254	$10,615	8%	35%	$13,404	$12,491	$10,256	7%	31%

[a] Estimate. [b] Includes military-related R&D programs of the departments of Defense and Energy. **Source:** Office of Management & Budget

last year's $4.1 billion, and a serious cut for the Defense Advanced Research Projects Agency (DARPA), down 13% to $1.3 billion. These defense agency budgets will not survive in Congress. Every year, SDI is cut back considerably (and this year, perhaps, even to levels below 1992) and the DARPA proposal is increased.

Within the several military branches, the Air Force gets the largest share of RDT&E funds, with $14.5 billion proposed for fiscal 1993. The defense agencies (mostly because of the development budget for SDI) are next with $10 billion, followed by the Navy with an $8.5 billion proposal and the Army with $5.4 billion.

Health & Human Services. The President's budget seeks about $10.6 billion for research at HHS, a 4% increase over fiscal 1992. The bulk of those funds go to the National Institutes of Health, which would garner a 5% increase to $9.4 billion. NIH, the largest single source of biomedical research support in the U.S., supplies about 30% of all federal funds for academic chemistry research.

Congress has long been generous with NIH, routinely voting to give the agency more money than the Administration asks for. In fiscal 1992, for example, Congress appropriated $8.9 billion for NIH, $160 million more than the President requested.

But Congress last year attached some unwelcome strings to its largess. Some $575 million of NIH's 1992 monies cannot be spent until Sept. 30, the last day of this fiscal year. The Administration had proposed some such "delayed obligations," which push the actual payments from the Treasury into 1993, but Congress increased the amount.

That accounting trick makes the overall federal budget look less sick, but could cause a lot of anxiety among researchers who depend on timely receipt of their grant money to keep their labs running smoothly.

The President's request for 1993 again includes delayed obligations, which this time would shove roughly $600 million of expenses into fiscal 1994.

NIH's budget request for fiscal 1993 would support a record number of research project grants—a total of 22,129,

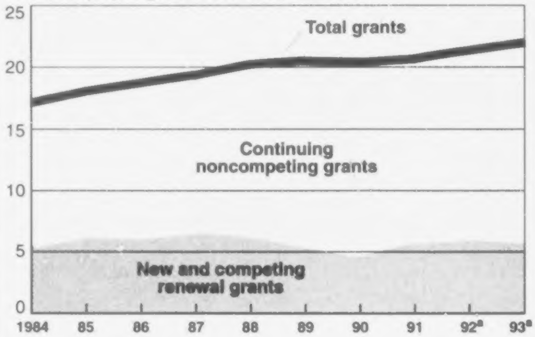
Across the board, NIH units register only modest increases

$ Millions	1993[a]	1992[a]	1991[b]	% change 1991–92
National Institutes	**$8481.7**	**$8101.4**	**$7434.8**	**5%**
Cancer	2010.4	1951.5	1711.6	3
(AIDS)	(175.9	168.8	159.8	4)
Heart, Lung & Blood	1245.4	1191.5	1126.0	5
(AIDS)	(48.2	46.2	46.4	4)
Allergy & Infectious Diseases	1010.8	960.9	907.0	5
(AIDS)	(470.8	449.5	432.0	5)
General Medical Sciences	862.1	815.1	757.9	6
(AIDS)	(17.0	16.1	15.6	6)
Diabetes & Digestive & Kidney Diseases	699.8	662.7	616.0	6
Neurological Disorders & Stroke	615.2	581.9	542.3	6
(AIDS)	(18.6	17.3	16.7	8)
Child Health & Human Development	545.2	519.7	479.0	5
(AIDS)	(38.2	36.1	32.6	6)
Aging	407.3	383.6	323.8	6
Eye	285.1	270.3	253.4	5
Environmental Health Sciences	261.5	252.0	240.6	4
Arthritis & Musculoskeletal & Skin Diseases	214.9	203.9	193.5	5
Dental Research	166.7	159.2	148.7	5
Deafness & Other Communication Disorders	157.3	149.1	135.0	5
National Center for Human Genome Research	**110.4**	**104.9**	**87.4**	**5**
National Center for Research Resources[c]	**330.2**	**314.6**	**335.8**	**5**
Other	**454.8**	**414.7**	**419.1**	**10**
TOTAL	**$9377.1**	**$8935.6**	**$8277.1**	**5%**

Note: Obligations for AIDS research are included in totals for each institute. Subtotals for AIDS are broken out where they exceed $10 million. **a** Estimate. **b** Actual. **c** Previously known as Division of Research Resources. **Source**: National Institutes of Health

Cut in new NIH grants hidden by record awards total

Research project grants awarded, thousands



a Estimate. **Source:** National Institutes of Health

Defense research sags after 1992 jump

$ Millions	1993[a]	1992[a]	1991[b]	% change 1992–93
Tactical programs	$13,242	$14,773	$12,815	-10%
Advanced technology development	7,653	6,421	5,199	19
Intelligence & communications	5,010	5,191	4,474	-3
Strategic programs	4,762	4,727	4,300	1
Technology base	4,084	4,215	3,849	-3
Program management support	3,857	4,097	4,018	-6
TOTAL	**$38,608**	**$39,424**	**$34,655**	**–2**

Note: Obligations. **a** Estimate. **b** Actual. **Source:** Department of Defense, Congressional Research Service

NASA boosts funding for space station, space research

$ Millions	1993[a]	1992[a]	1991[b]	% change 1991–92
Space station	$2238.9	$1986.8	$1931.3	13%
Scientific investigations in space	1775.4	1751.6	1578.7	1
Physics & astronomy	1110.2	1071.6	971.6	4
Planetary exploration	489.6	532.0	474.9	−8
Life sciences	175.6	148.0	132.2	19
Space applications	1196.1	1065.0	795.8	12
Aeronautical research & technology	884.4	767.0	505.6	15
Space transportation capability development	857.1	808.8	566.2	6
Space research & technology	361.1	313.9	297.7	15
Commercial programs	170.5	155.1	81.7	10
Transatmospheric vehicle	77.0	20.9	95.8	268
Academic programs	71.2	77.4	50.5	−8
Safety, reliability & quality assurance	32.6	36.8	32.1	−11
Tracking & data systems	23.1	21.4	20.0	8
TOTAL	$7687.4	$7004.7	$5955.4	10%

Note: Obligations. **a** Estimate. **b** Actual. **Source:** Office of Management & Budget

Funds for global-change research continue strong growth

$ Millions	1993[a]	1992[a]	1991[a]	% change 1992–93
NASA	$ 890.8	$ 755.9	651.6	18%
NSF	162.5	108.5	87.1	50
Energy	113.0	77.0	65.6	47
NOAA[b]	78.2	47.0	47.0	66
USDA	47.6	44.3	38.6	7
Interior	35.8	39.4	36.6	−9
EPA	26.0	24.0	21.8	8
Smithsonian	10.6	6.3	5.4	68
Defense	6.6	6.3	0	5
HHS	1.2	1.0	0	20
TVA[c]	0.1	0.1	0	0
TOTAL	$1372.4	$1109.8	$953.7	24%

Note: Budget authority. **a** Estimate. **b** National Oceanic & Atmospheric Administration. **c** Tennessee Valley Authority. **Source:** Office of Science & Technology Policy's Committee on Earth & Environmental Sciences

up from 21,671 projected for fiscal 1992. About three quarters of those, however, are continuing grants. The number of new and competing renewal grants would actually drop about 200 to some 5800 in fiscal 1993.

It was just such a drop in new grants that caused such consternation in 1989 and again in 1990, when the number of new grants awarded declined to fewer than 5000. The more modest drop proposed for 1993 may well renew the research community's fears about inadequate funding.

Perhaps as upsetting to the scientific community, however, is the outlook for training supported by NIH. The proposed 1993 budget would freeze training monies at $309 million—exactly the same level as 1992 and only a few million more than 1991.

"It's going to be a problem," says Marvin Cassman, deputy director of the National Institute for General Medical Sciences (NIGMS). That institute, which is the source of most NIH chemistry funding and which supports a higher proportion of predoctoral students than other NIH units, has been hoping to start a new chemistry-biology fellowship program.

NIGMS's budget would fare slightly better than NIH's as a whole, increasing 6% to $862 million in fiscal 1993. Within NIGMS, the pharmacological sciences program would increase 7% to $130 million; cellular and molecular bases of disease 7% to $239 million; and biophysics and physiological sciences 8% to $177 million.

After several years of huge percentage increases, the National Center for Human Genome Research at NIH would get only a 5% increase to $110 million in fiscal 1993. The project to map and sequence human chromosomes also receives funds from the Department of Energy.

Funds for the human genome project are included in the new Biotechnology Research Initiative that OSTP is introducing for fiscal 1993. The President's budget overall proposes $4 billion for biotechnology research programs in 15 agencies.

R&D addressing AIDS would increase 4% at NIH to $873 million. Those funds would be spread across the various institutes, although the National Institute for Allergy & Infectious Diseases commands more than half. Another $1.2 billion for AIDS research, treatment, and prevention is requested for other parts of the Public Health Service, including the Centers for Disease Control, the Food & Drug Administration, and the Alcohol, Drug Abuse & Mental Health Administration.

National Aeronautics & Space Administration. According to NASA Administrator Richard H. Truly, the fiscal 1993 budget required NASA to "make tough choices because of the constraints placed on our rate of growth for this year." That's not too evident in its fiscal 1993 R&D budget request, which proposes a 10% hike to $7.7 billion. If that goes through, R&D will make up 54% of NASA's total budget of $14.3 billion.

Once again, close to one third of NASA's R&D funds would go to the controversial space station, funding for which would increase 13% over fiscal 1992. Last year the space station was redesigned. In fiscal 1993 the new design will be reviewed and finalized. Also, various critical components of the space station will be fabricated and tested in preparation for a planned launch of some elements of the station in early 1996. Funding is also included for research on a vehicle to return the crew to Earth from the orbiting space station.

Funds for scientific research in space would receive only a 1% boost in fiscal 1993 to $1.8 billion. This consists of research in physics, astronomy, life sciences, and planetary exploration. Funds for building two low-cost robotic systems to map the terrain and resources of the Moon are requested.

Despite President Bush's announced initiative to make U.S. students world leaders in mathematics and science achievement by 2000, the requested funds for academic programs funded by NASA would decline 8% from fiscal 1992 to $71 million.

Glossary of budget terms

Budget authority. The authority provided by federal law enacted by Congress to incur financial obligations that will result in outlays.

Fiscal year. The fiscal year is the government's accounting period. It begins on Oct. 1 and ends on Sept. 30, and is designated by the calendar year in which it ends.

Obligations. Binding agreements that will result in outlays, immediately or in the future. Budgetary resources must be available before obligations can be incurred legally.

Outlays. Payments for obligations incurred under Congressionally granted budget authority generally made by issuance of checks on the Treasury. Outlays during any fiscal year may be made for obligations incurred in prior fiscal years or in the same fiscal year.

Note: The R&D numbers supplied by individual agencies frequently differ from those used by the Office of Management & Budget in preparing its analysis of total federal R&D funding

SSC receives largest chunk of energy R&D funds

$ Millions	1993[a]	1992[a]	1991[b]	% change 1993–92
ENERGY R&D	**$5638.3**	**$5289.6**	**$4573.6**	**7%**
General science & research	**1644.4**	**1467.3**	**1158.1**	**12**
Superconducting Super Collider	650.0	484.4	265.0	34
High-energy physics	630.9	628.2	582.7	0
Nuclear physics	363.5	354.7	310.4	2
Supporting research & technical analysis	**884.1**	**854.5**	**756.1**	**3**
Environmental restoration & waste management	**707.0**	**610.5**	**432.4**	**16**
Clean-coal technology	**500.9**	**415.0**	**386.4**	**21**
Biological, environmental	**384.7**	**353.3**	**386.5**	**9**
Fusion	**359.7**	**337.7**	**283.6**	**7**
Conservation	**329.8**	**271.2**	**220.2**	**22**
Fossil	**311.3**	**444.3**	**454.8**	**−30**
Nuclear	**309.6**	**332.1**	**299.1**	**−7**
Solar	**206.8**	**203.7**	**196.4**	**2**
DEFENSE R&D	**1414.2**	**1466.3**	**1215.8**	**−4**
TOTAL	**$7052.5**	**$6755.9**	**$5789.4**	**4%**

Note: Obligations **a** Estimate **b** Actual **Sources:** Department of Energy, Office of Management & Budget

NASA's Mission to Planet Earth would receive a boost of 12% to $1.2 billion. The largest fraction of these funds, $308 million, is targeted for the Earth Observing System, six huge satellites to be launched on a variety of expendable launch vehicles that would monitor many processes on Earth simultaneously. Funds for the Earth Observing System would increase 64% from the $188 million in fiscal 1992.

Several Earth probes are also funded under the Earth mission budget. One is a total ozone mapping spectrometer and another is a probe to map tropical rainfall. Funds to replace an aging Landsat satellite are also proposed.

The Earth Observing System and the Earth probe satellites are part of NASA's contribution to the U.S. global-change research program, an interagency effort coordinated by OSTP's Committee on Earth & Environmental Sciences. The Administration is requesting almost $1.4 billion, up 24% from 1992, for research projects aimed at better understanding global environmental issues such as climate warming and ozone depletion.

Those funds are spread over 11 agencies, some with only very small programs. As it has since the coordinated program was initiated in 1989, NASA would claim more than half of the funds—$891 million, up 18% from fiscal 1992. But the President also requested hefty increases for global-change research at several other agencies taking part: a 50% increase to $163 million for NSF, a 47% rise to $113 million for DOE, and a 66% increase to $78.2 million for the National Oceanic & Atmospheric Administration.

Department of Energy. Research funding for the Department of Energy is slated to rise 4% to $7.0 billion in an overall agency budget that would rise only 2% to $19.4 billion. Research thus would account for 36% of DOE's total budget. Funding for DOE's energy supply R&D activities would be up 7% to $5.6 billion, while that for nuclear defense R&D activities would fall 4% to $1.4 billion.

As it did last year, DOE's proposed energy R&D budget benefits from an emphasis on research aimed at advancing the Administration's National Energy Strategy, which has yet to be endorsed by Congress. The President proposes $914 million, an increase of 18% or $140 million, for R&D initiatives for that strategy. DOE's share of the funding would rise 16%, or $99 million, to $725 million.

DOE's research budget also would benefit somewhat from three other of this year's five Presidential science and technology initiatives. It would get 37%, or $678 million, of the amount budgeted for advanced materials processing, an increase of $75 million; 14%, or $109 million, of what's budgeted for high-performance computing, an increase of $17 million; and 3%, or $107 million, of the amount budgeted for biotechnology, an increase of $27 million. Of biotechnology funding, $64.7 million would support DOE's work on the human genome project. Funding for DOE's math and science education activities wouldn't decline in fiscal 1993, as NASA's would, but it would be up just 2% to $114 million.

The budget proposal sets funding for DOE's basic energy sciences program at $644 million, up 12% from 1992. Within that category, funding for chemical sciences is up 11% to $175 million, with research funding up 13% to $115 million, and facilities operations up 6% to $60.3 million. The chemical sciences budget includes $16.8 million for support of biotechnology activities, $3.1 million for materials research, and $900,000 for math and science education.

Funding for materials sciences would rise 13% to $290 million. Of that, research funding would increase 6% to $169 million, and facilities operations funding would rise 24% to $121 million. Funding for DOE laboratories accounts for about 45% of materials sciences research funding, and universities account for about 15%. The materials sciences budget request includes $2.2 million, a 16% increase, for biotechnology research activities.

National Science Foundation. With a budget rise of 18%, NSF has every reason to feel jubilant about its treatment by the Bush Administration. A commitment was made in the mid-1980s to double NSF's budget over a five-year period, and that effort continues at a pace that would be completed in fiscal 1994, if Congress would just go along with the idea. However, it hasn't shown any sign of doing that so far.

If NSF's request does hold up in Congress, though, the agency would for the first time crack the $3 billion mark. The interesting feature of NSF's budget is that just about all of the increase is accounted for by various initiatives organized under FCCSET—global change, high-performance computing and communications, biotechnology, and advanced materials and processing.

The only initiative that would not receive any significant increase in funding at NSF is mathematics and science education, which would rise only about 3%, from $465 million to $479 million. But as NSF director Walter E. Massey points out, the fiscal 1993 figure "is more than double the level of just two years ago." Massey says a "revolutionary" fruit of that activity has been the statewide systemic initiatives for reform of precollege math and science. And he says a leveling out now will give NSF the chance to "look at ways of better coordinating the funding for all our education and human resources programs."

Indications are that Congress won't mind a little breather in growth for that NSF program. "From our perspective," says one House committee staffer, "we want to see the program consolidated, so we have no trouble with an off-funding year."

Highlights of NSF's fiscal 1993 budget allocations also include:

- $2.21 billion, an 18% increase, in research and related activities, which NSF says will mean that more individual investigators and small groups will see increased funding availability. The chemistry division would get $126 million, up almost $14 million.
- $319 million for advanced materials and processing, a 20% increase. Chemistry's portion of the increase is $5 million, off a 1992 base of $13 million.
- $280 million for environmental and global-change research, a rise of 30%. Chemistry's portion is $2.9 million, added to a 1992 base of $4.3 million.
- $262 million for high-performance computing and communications, up 30%.

NSF's budget is up 18% overall . . .

$ Millions	1993^a	1992^a	1991^b	% change 1992–93
Mathematical & physical sciences	$ 726.0	$ 623.1	$ 564.1	17%
Education & human resources	479.5	465.0	321.9	3
Geosciences	472.4	404.4	367.7	17
Biological sciences	320.6	274.3	255.1	17
Engineering	312.5	258.5	237.7	21
Computer & information science & engineering	272.2	210.9	189.5	29
Antarctic program	163.0	88.4	175.1	84
Salaries & expenses	135.0	109.1	100.9	24
Social, behavioral, & economic sciences	107.8	85.9	79.2	25
Academic research facilities & instrumentation	33.0	33.0	39.0^c	0
Inspector General	4.0	3.9	2.9	3
TOTAL	$3026.0	$2557.0	$2333.1	18%

. . . with funding for the sciences up 14% . . .

$ Millions	1993^a	1992^a	1991^b	% change 1992–93
Ocean sciences	$ 206.4	178.8	$ 164.6	15%
Materials research	167.5	143.6	134.1	17
Atmospheric sciences	151.9	127.2	116.6	19
Physics	148.6	138.4	130.0	7
Chemistry	126.0	112.3	104.7	12
Astronomical sciences	120.0	112.3	100.0	7
Molecular & cellular biosciences	95.5	82.9	76.7	15
Integrative biology & neurosciences	88.5	77.1	72.4	15
Earth sciences	88.1	76.2	70.8	16
Environmental biology	86.5	72.7	68.3	19
Mathematical sciences	85.0	78.6	73.1	8
Social, economic sciences	49.1	40.5	35.9	21
Behavioral, cognitive sciences	24.9	22.2	20.7	12
TOTAL	$1438.0	$1262.8	$1167.9	14%

. . . and that for chemical programs up 15%

$ Millions	1993^a	1992^a	1991^b	% change 1992–93
Materials research	**$167.5**	**$143.6**	**$134.2**	**17%**
Project support	96.4	77.4	69.2	25
Laboratories, groups	51.4	48.0	47.2	7
Facilities, instrumentation	19.7	18.2	17.8	8
Chemistry	**126.0**	**112.3**	**104.7**	**12**
Physical	35.2	32.5	30.6	18
Organic & macromolecular	29.9	27.0	25.9	11
Inorganic, bioinorganic, & organometallic	20.6	18.3	17.6	13
Special projects	18.5	14.0	8.8	32
Analytical & surface	15.7	14.4	13.7	9
Instrumentation	6.1	6.1	8.1	0
Chemical & thermal systems engineering	**43.7**	**36.5**	**33.0**	**20%**
Interfacial, transport, & separations processes	11.4	9.4	8.7	21
Fluid, particulate, & hydraulic systems	11.4	10.2	9.3	12
Chemical reaction processes	10.9	8.4	7.3	30
Thermal systems	10.0	8.5	7.7	18
Biochemistry & molecular structure & function	**38.0**	**33.5**	**31.3**	**13%**
TOTAL	$375.2	$325.9	$303.2	15%

Note: Obligations **a** Estimate **b** Actual **c** Funds for facilities only **Source:** National Science Foundation

Of that, only $700,000 goes to the chemistry division. But as chemistry division director Kenneth G. Hancock says, the division is already spending $10 million to support computational chemistry work.

- $206 million for biotechnology research, a rise of 18%. The chemistry division's slice is $3.3 million, added to an already existing base of $10 million.
- $153 million for NSF's various centers, a 9% rise. Two new centers are planned in the fields of manufacturing and materials processing.
- $146 million for undergraduate programs, a rise of 16%. Chemistry's portion is $3 million.
- $105 million for advanced intelligent manufacturing, an increase of 31%. What is being sought here, according to Massey, is "the total integration of design, manufacturing, and business management practices that can lead to developing prototype products and processes quickly." Chemistry has no involvement in this program, although projects to support environmentally benign chemical processing research are in the works.
- $33 million for academic research instrumentation and facilities—but no increase over the past year's and thus disappointing to those in university laboratories.

Overall, NSF's chemistry division budget would rise 12% in fiscal 1993. "It's the best budget request for chemistry in five years," notes Hancock.

Cuts sought in USDA research

$ Millions	1993[a]	1992[a]	1991[b]	% change 1992–93
Agricultural Research Service	$ 721.6	$ 718.9	$ 672.0	0%
Cooperative State Research Service	416.0	508.9	454.3	-18
Forest Service Research	173.7	184.1	186.0	-6
TOTAL	$1311.3	$1411.9	$1312.3	-7%

Note: Obligations **a** Estimate **b** Actual **Source:** Department of Agriculture

Multimedia research driving EPA R&D

$ Millions	1993[a]	1992[a]	1991[b]	% change 1992–93
Multimedia	$176.6	$153.7	$120.9	15%
Air	129.2	126.7	101.0	2
Superfund	68.9	66.8	83.8	3
Hazardous waste	42.9	47.8	39.9	-10
Water quality	32.6	30.5	28.0	7
Toxic substances	26.8	25.3	25.5	6
Drinking water	21.9	22.1	18.9	-1
Pesticides	15.8	14.5	11.9	9
Management & support	5.3	5.3	5.1	0
Radiation	5.1	3.5	3.9	45
Leaking underground storage tanks	0.8	0.8	0.8	0
TOTAL	$525.9	$497.0	$439.7	6%

Note: Obligations **a** Estimate **b** Actual **Source:** Environmental Protection Agency

Equally excited is Henry McGee who heads the chemical engineering division (formally titled chemical and thermal systems) in NSF's engineering directorate. That division's budget would rise 20% to $43.7 million. Initiative work is mainly covered by a $4.3 million increase for advanced materials and processing, plus another $1.2 million in biotechnology.

"This research budget," says NSF director Massey, "highlights our need to make connection to those outside the immediate sphere of scientific research, especially in some of the more strategic areas. We're doing this by emphasizing in our budget ways to develop stronger partnerships in the form of interdisciplinary research efforts, as well as between researchers, educators, government, and industry."

Thus, although the foundation says it is increasing support for individual investigators and small groups (by 17%), the intention is not necessarily to fund more pure research. Rather, it means that individual investigators will stand a better chance of being funded if they relate their proposals to economic and "quality of life" uses by establishing what Massey calls "partnerships" with the industrial community.

Department of Agriculture. The Bush Administration is asking for $1.3 billion for research at USDA in fiscal 1993—about the same as it requested last year but 7% less than Congress actually ended up appropriating.

The Agricultural Research Service, which conducts basic and applied research at federal labs, would get $722 million, about the same as last year. The Forest Service would receive 6% less research support overall, although small increases are proposed for research related to wetlands, forest health monitoring, and recycling.

USDA's Cooperative State Research Service (CSRS) faces a cut of 18% from 1992 levels to $416 million. Each year the Administration takes monies for facilities and special grants out of CSRS's budget. Congress just as regularly puts it back. These earmarked funds, which send money directly to Senators' and Representatives' favorite projects, prove stubbornly difficult to uproot.

Within CSRS, however, the program of competitive grants known as the National Research Initiative would increase 54% to $150 million under the President's request. That program supports the only research grants at USDA that are distributed under a competitive peer-review process. Proposed in a 1989 report by the National Academy of Sciences, the initiative aims to apply advanced research tools to agricultural problems.

Competition for the grants is keen, despite a cap of 14% on overhead costs imposed a few years ago by Congress. "We are turning down more good science than we can fund," says the initiative's chief scientist, Arthur Kellman. "It's heartbreaking to see how much good research is not being funded."

Environmental Protection Agency. Delving into environmental issues that affect more than one medium has not been a hallmark of EPA research in the past. However, the agency has become increasingly aware of the difficulty in pigeonholing much research into specific environmental media. Thus, multimedia research not only is slated for the biggest increase in EPA's fiscal 1993 budget, up 15% over 1992 to nearly $180 million, but also accounts for the largest single chunk of the R&D budget.

Nevertheless most of EPA's research funding is still di-

Materials sciences R&D funds up 30% at NIST

$ Millions	1993[a]	1992[a]	1991[b]	% change 1993–92
Scientific & technical research & services	**$199.0**	**$172.5**	**$167.6**	**15%**
Materials science & engineering	38.0	29.2	25.7	30
Physics	28.1	26.3	25.1	7
Electronics & electrical engineering	28.0	23.7	18.8	18
Research support	**25.0**	**24.2**	**18.5**	**3**
Chemical sciences	20.6	18.7	18.3	10
Computer systems	17.3	11.9	11.6	45
Manufacturing engineering	12.8	9.5	8.7	35
Building & fire research	12.2	11.0	10.8	11
Other	17.0	18.0	30.1	−6
Industrial technology services	**86.1**	**102.7**	**49.1**	**−17**
TOTAL	**$285.1**	**$275.2**	**$216.7**	**4%**

Note: Obligations **a** Estimate **b** Actual **Source:** Office of Management & Budget

NIH claims bulk of biotechnology research funds

$ Millions	1993[a]	1992[a]	1991[b]	% change 1992–93
NIH	**$2943.9**	**$2800.6**	**$2526.3**	**5%**
Energy	242.7	181.9	152.7	33
NSF	206.0	174.0	162.0	18
Agriculture	167.7	179.4	161.6	−6
ADAMHA[c]	111.2	94.0	79.0	18
Veterans Affairs	88.4	85.6	80.6	3
Defense	86.6	81.0	79.6	7
NASA	44.7	36.6	26.5	22
FDA	36.2	34.7	28.8	4
CDC[d]	33.7	33.7	28.6	0
AID[e]	30.7	21.5	19.0	43
EPA	18.3	15.9	14.3	15
Commerce	13.0	13.0	12.7	0
Interior	5.0	5.2	5.9	−4
Justice	2.3	2.2	1.8	5
TOTAL	**$4030.4**	**$3759.3**	**$3379.4**	**7%**

Note: Budget authority. **a** Estimate. **b** Actual. **c** Alcohol, Drug Abuse & Mental Health Administration. **d** Centers for Disease Control. **e** Agency for International Development. **Source:** Office of Science & Technology Policy's Committee on Life Sciences & Health

rected toward meeting legislative mandates or assessing data from existing programs, so-called media-specific research. Of the $526 million requested for research in fiscal 1993, only $172 million, up $12.3 million, is pegged for basic research.

The biggest part of the regulatory research effort will be directed toward implementing the 1990 Clean Air Act Amendments, which will receive $102 million of the total $131 million to be used for research underpinning new regulations. EPA says emphasis will be on monitoring for compliance with new ozone standards in metropolitan areas, air pollution from motor vehicles, and health concerns of air toxics. Another research project will address neurotoxicological effects of pesticide residues on foods.

Other R&D themes stressed by EPA in fiscal 1993 include clusters and international support. The cluster concept is designed to take a multidisciplinary approach to environmental problems, helping to solve complex issues without as much duplication. EPA says it will provide $31.5 million to research cluster projects, with the major effort focused on understanding how to monitor and reduce indoor air pollution problems. Funding for the agency's international research support effort would increase $8.2 million to $58.2 million in fiscal 1993. Primary areas of emphasis will be global climate change, high-performance computing, advanced materials, and biotechnology.

National Institute of Standards & Technology. With a 26% boost in its total budget request, NIST—formerly the National Bureau of Standards—enjoys an even bigger percentage increase than NSF. NIST's budget would increase from $247 million to $311 million with the big emphasis on stimulating the commercialization of new technologies. As NIST's director, John Lyons, puts it, the budget "greatly expands our outreach efforts to industry, improves our capability to acquire and disseminate superior expertise on the latest technologies, and creates a positive environment for research advances that will fuel new product development and economic growth."

NIST's 1993 budget request would provide, among other things:

- $202 million for intramural laboratory research and supporting services, a 13% increase over current funding.
- $67.9 million for the Advanced Technology Program, up 36%.
- $17.8 million for manufacturing technology centers, up 13%.
- $22.7 million for facilities construction.

Under Lyons, NIST has been gingerly moving toward becoming the prime federal center for stimulating industrial innovation in critical technologies such as advanced semiconductor fabrication, biosensors, high-speed digital communications, and new engineering concepts. Some of the other high-priority items within NIST include research in magnetic media, advanced materials, chemical processing techniques, and computer and telecommunications technologies.

In fiscal 1993 NIST plans to support more advisers in U.S. embassies to help break down standards-based trade barriers in foreign countries. And it will boost NIST's capabilities in atomic-scale structures and interactions. NIST's outside work now accounts for about a third of its total budget. In fiscal 1989, that amount was only about 10%.

Any analysis of an Administration budget proposal must conclude with the warning that the Administration proposes, but Congress sets final budgets, as is its duty under the Constitution. The majority of the numbers in the Administration's budget proposal will be revised, either upward or downward, before a final fiscal 1993 budget is in place. If recent history is any indication, funding for most research programs probably will increase slightly. ☐

Taiwan's Petrochemical Industry Entering New Developmental Phase

■ ***Focus is now on intermediate chemicals and optimization of their mix, prompting construction of new naphtha crackers***

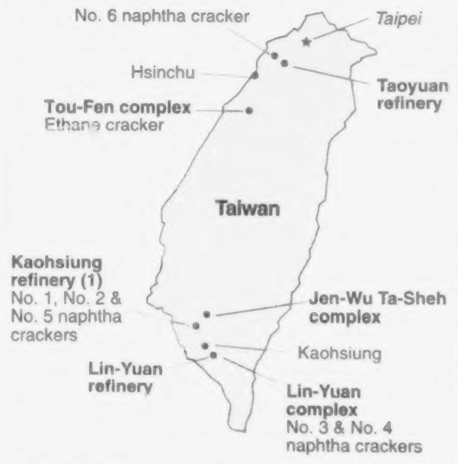
Joseph Haggin, C&EN Chicago

The petrochemical industry in Taiwan is about to enter another developmental phase at the same time that the national economy is shifting emphasis. Jer-Ru Maa, president of National Cheng Kung University, characterizes the shift as being from a capital-intensive to a technology-intensive mode.

A less cryptic characterization, offered by a more candid observer, is that like other "microtigers" in the Far East, such as South Korea or Singapore, Taiwan is faced with the problem of generating its own commodities, and the most salable one at the moment happens to be technology. The advantages of cheap labor that formerly accrued to the microtigers have faded somewhat. Without natural physical resources, the smaller countries are losing the competitive advantage they formerly enjoyed in a world marketplace.

An added problem for Taiwan is its relations with China. But the Kuomintang, Taiwan's major political party, captured 71% of the popular vote in national elections last Dec. 21. The strength of this nationalist party thus obviates any need for further rhetoric concerning "reform, stability, and prosperity" through improved relations with China. More consistent government policies are expected to result, and the chemical industry likely would be a beneficiary.

Six naphtha crackers are located throughout Taiwan



The key to Taiwan's petrochemical industry is the slate of intermediate chemicals from its refineries. These provide the feedstocks for fibers, plastics, rubbers, and specialty chemicals. They also serve as the indirect source for some pharmaceuticals.

The immediate aim of the petrochemical industry is to increase the added value of the products produced rather than to expand the volume of lower value commodity chemicals. Considering the very close mutual dependence among the various parts of the industry, making the best use of the intermediates is a classic problem in optimization.

In optimizing the intermediate mix, greater attention will be given to control of the molecular weights and purities of the various intermediates, much as a refiner does who wants to control the research octane number of the fuel in the gasoline pool. Molecular weight control is crucial for specialty chemicals manufacture. Process development in the future is to be integrated with selection of intermediates to specifically target terephthalic acid, phenolic derivatives, styrene derivatives, and the C_4/C_5 fractions. Catalysis and process control will become dominant disciplines in the immediate future.

One of the industrial groups targeted for special promotion is the pharmaceutical industry. By the year 2000, this industry is projected to have a production value of about $160 million (based on one Taiwan dollar = $0.0397 on Jan. 16), fueled by a bigger population, a higher living standard, a national health insurance program, and exports.

Included among development centers for pharmaceuticals is Union Chemical Laboratories in the Industrial Park at Hsinchu. The company's principal products include anti-inflammatory drugs (acetaminophen, ibuprofen, naxproxen), antibiotics (PenG and CephC series), and cardiovascular agents (inositol, atenolol) and a new dosage form of these agents. The keys to these and other developments are strong commitments to chiral syntheses, racemic resolution, and new transdermal delivery formulations. The company claims these methods will involve a new generation of biosynthesis and processes for making generic and bulk pharmaceuticals.

Among the specialty chemicals Union Chemical is focusing on are modifiers for plastics—for example, reactant impact modifiers, polymer antioxidants, and linear alcohol plasticizers. Also in the works are silicon- and fluorine-containing specialty chemicals for textiles. Much attention will be given to controlled release techniques for the delivery of some of these specialty chemicals for long-service applications.

In the area of functional polymers, emphasis will be on polyphenylene sulfide and the

Taiwan petrochemical feedstocks come mainly from naphtha crackers

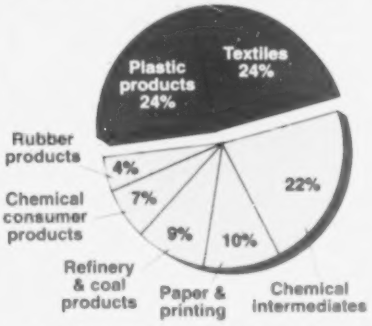
Company location	Cracker No.	Installation date	Ethylene capacity (thousands of metric tons per year)	Type
China Petrochemical Co.				
Kaohsiung	1	1968	54	Naphtha
	2	1975	230	Naphtha
Lin-Yuan	3	1978	230	Naphtha
	4	1984	385	Naphtha
Kaohsiung	5	1993	400	Naphtha
Formosa Plastics Corp.				
(Undecided)	6	—	450	Imported naphtha
China Petrochemical Development Corp.				
Tou-Fen	—	1973	54	Ethane

polysulfones. Additional emphasis will be on polymeric membranes, biodegradable and biomedical polymers, and the technology for producing them.

Synthetic fibers are also of special interest because so much of Taiwan's chemical business is aimed at synthetic fabrics. The emphasis at Union Chemical is currently on development of ultradenier fibers (especially those with fire-retardant characteristics), hollow fibers, and nonwoven materials. One of the more intriguing developments is the emergence of chromophoric fibers, from which garments are made that change color in response to varying light intensities. Several of these chromophoric fibers are nearly ready for commercialization.

The importance of petrochemical intermediates in the near future has prompted two major developments. First is a modernization of the sources for intermediates, specifically the building of new and the scrapping of old naphtha crackers. Second is optimization of the intermediates mix. Nearly all of the feedstocks for the Taiwan petrochemical industry come from the naphtha crackers that are associated with refineries of Chinese Petroleum Corp. (CPC). Wenent P. Pan, vice president for corporate planning, and Hsin-Hsing Tsai, executive secretary of the R&D advisory committee, both for CPC, note that modernization of the refining facilities is now under way and that some new naphtha crackers are either under construction or in the planning stages.

Plastics, textiles are big part of Taiwan's chemical output



1990 production = $560 million

Soon the first two naphtha crackers to have been built in Taiwan will be scrapped and replaced by new ones. In the process, total capacity from the new crackers will be increased. In all cases, the principal product will be ethylene.

A total of six naphtha crackers are now on the books to be operated by various interests. In addition to these naphtha crackers, a small ethane cracker also is operated by China Petrochemical Development Corp. at Tou-Fen. Cracker No. 5 is under construction near Kaohsiung and No. 6 is still in the design stages. The location has not been specified, but No. 6 is expected to be located between Taipei and Hsinchu, with construction starting probably in 1994. Total production of all six crackers has been projected to be about 1.8 million metric tons per year of ethylene. When No. 1 and 2 crackers are scrapped, production will be reduced by 284,000 metric tons per year.

Optimizing the output of the naphtha crackers is the focus of one new government project aimed at increasing the competitive position of Taiwan's petrochemical industry. According to Johnsee Lee, deputy general director of the Industrial Technology Research Institute (ITRI), his organization has been given the job of doing the optimization. The object is to target the products and processes that would be most suitable for Taiwan. To this end, Chem Systems Inc. of the U.S. has been retained as an independent contractor.

In the first phase of the project, to be completed three months after the start of the job, Chem Systems will identify market potentials, global competition, investment risk, raw materials sources, technology sources, and the strengths and weaknesses of the Taiwan industry. Chem Systems will also recommend target products and processes for further research and development.

In the second phase of the project, more detailed assessments will be made. This phase is expected to be completed within eight months of the start of the project, at which time the government will seek to attract private investment in support of necessary R&D. An advisory group from industry, Union Chemical, and ITRI will assist Chem Systems. The entire project is scheduled to be completed this fall.

Not all of Taiwan's petrochemical industry is in Taiwan. There are at least nine overseas companies currently operating in the U.S., the Philippines, Singapore, Malaysia, Saudi Arabia, and Canada. All of these operations are based on ethylene and aromatics production.

Some of these overseas operations have had problems. In one case, the Taiwan government has been at odds with Wang Yung-ching, president of Formosa Plastics Corp. and possibly Taiwan's richest man. In 1990, reports suggested that Wang made an unauthorized trip to China to talk about a possible petrochemical project in Fujian Province. To avoid difficulties with Taiwan, Wang moved to the U.S., where his company has several chemical plants in Texas. The future of the Fujian project is in doubt since most of the capital probably would come from the nationalized banks in Taiwan, which would be guided by government policies not favoring China.

However, Wang might also raise the capital outside Taiwan.

With expansion and optimization expected for Taiwan's petrochemical industry, considerable catalysis R&D will have to be carried out. Much of this work will be done by the Catalyst Research Center (CRC), a unit of China Technical Consultants Inc. CRC was founded in 1981 as a joint venture of China Petrochemical Development Corp. and China Technical Consultants, mainly to serve as the corporate R&D facility for China Petrochemical Development. In 1984, the center was reorganized and became a formal unit of China Technical Consultants with a 12-year renewable cooperation agreement with China Petrochemical Development. It also serves local industries and conducts contract research from other sources.

Chun-Mann Tsao, deputy director of CRC, says the center currently has about 100 people and a 1991 budget of some $4 million, roughly divided into 30% from in-house research and 70% from contract research. The contract research is performed for CPC, China Petrochemical Development, the government, and elements of the private sector.

A major effort at CRC is devoted to catalyst development with special emphasis on the process. Particular attention is given to polymeric materials synthesis, compounding polymers, analysis connected with process control, and antipollution measures. Among the technological developments now available from CRC is a new catalytic converter for automobiles and motorcycles. This is of particular importance to Taiwan, where there is a plethora of two-stroke cycle motorcycle engines, which are notorious polluters. CRC also offers its own technology for such things as catalytic tailgas cleanup, a molybdate-based ammoxidation catalyst, aniline from phenol, and carbon fiber precursors. The center is now operating in the administration building of an obsolete ethylene plant that is being scrapped in preparation for a new venture.

Trading in pollution rights nearer reality

The Chicago Board of Trade will be under intense scrutiny in the months ahead, because late last month it became the first exchange to propose to operate the Environmental Protection Agency's sulfur dioxide pollution rights sales program.

An environmental group, the Environmental Defense Fund, first proposed an emissions trading system under the theory that if the number of allowances granted to utilities that emit sulfur dioxide is less than the amount of SO_2 they emitted in recent years, they would be forced to cut emissions or buy more allowances on the market (C&EN, Nov. 18, 1991, page 20). Because EPA will impose a $2000-a-ton penalty on utilities that exceed their allowances, any utility that can cut emissions, or obtain allowances for less than $2000 a ton, has an incentive to do so. An EPA spokesman says that although utilities could acquire more emission allowances than they were originally granted, the utility still could not exceed local government emission limits.

The EPA's program seeks to control acid rain through limiting total coal- and oil-burning electric utility emissions to 8.9 million tons of SO_2 per year by the year 2000 from a current 16 million tons (C&EN, May 27, 1991, page 18). The Chicago Board of Trade figures into the equation as the point of sale, auction, and registry of 2.8% of SO_2 emission allowances available for sale in any one year. Operating utilities automatically receive, at no cost, 97.2% of allowances based on past emissions. The first EPA-sanctioned auction and sale would be in 1993 for allowances first usable in 1995 and thereafter. Any citizen, broker, utility, or group may purchase the emission allowances, each allowance permitting the emission of 1 ton of SO_2. And further, owners may sell the rights to any other citizen, broker, utility, or group.

At least one other exchange, the New York Mercantile Exchange, is "seriously considering" making a proposal to EPA. However, it must do so by EPA's Feb. 21 deadline if it intends to seek authority to operate EPA's pollution rights sale and registry.

Since the passage of the 1990 Clean Air Act, in which Congress authorized the creation of a system of transferrable emission allowances, the South Coast Air Quality Management District in California has said it too plans a free market system to control sources of smog and to lower atmosphere ozone. In addition, the United Nations has issued a report in Geneva that proposes world trading in carbon dioxide emission allowances in an effort to control global warming. One author of the UN report is a director of the Chicago Board of Trade. A spokesman for the board says the exchange also would be interested in running an international carbon dioxide emission allowances market.

Not only is the Chicago Board of Trade the first to publish its plan to operate EPA's annual auction and sale of SO_2 emission rights, but it also has made public two additional proposals that together would constitute a well-organized trading system for emission rights. The board filed a proposal in September with the Commodity Futures Trading Commission, which if approved, would allow the board to operate a market beginning late this year to sell the right to emit SO_2 at a predetermined date in the future. The futures market would allow utilities to purchase future emission allowances as a hedge against higher priced emission allowances in the future. In addition, the board has offered to run a "spot" market that would allow utilities to buy or sell current SO_2 emission rights.

In addition to the enthusiasm the board has shown to trade SO_2 emission allowances, and the New York Mercantile's statement of interest, the American Stock Exchange has indicated it would like to get into the act. An American Stock Exchange spokesman says it might set up a market to trade SO_2 emission options. Trading in options allows the buyer the right to buy or sell a commodity such as an SO_2 emission allowance at a specified price during a specified contract period. Trading in options would be another hedge for utilities, allowing them to secure emission allowances for a nominal fee without having to buy the emission allowances outright.

Electric utilities and even the Chemical Manufacturers Association are generally sanguine about the emission rights approach to limiting SO_2 emissions. A spokesman for Edison Electric Institute, a Washington, D.C.-based association of investor-owned utilities, says that electric utilities are committed to making the trading system work.

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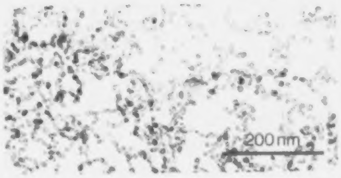

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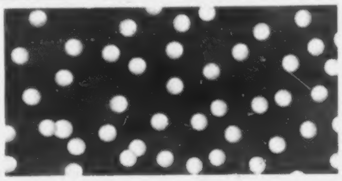

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"We like the whole concept." The association is a little more tentative about prospects for limiting carbon dioxide emissions under UN auspices, or even for the proposals to utilize market forces to limit emissions in Southern California: "It's a very new idea. We need to have the bugs worked out."

CMA "in general" likes emission trading proposals, too, because they offer "an efficient way to allocate resources," says Richard G. Sigman, air program associate director.

Not all environmental groups, however, agree that market forces are the best approach to limiting emissions. David Hawkins, a senior attorney for the Natural Resources Defense Council in Washington, D.C., "supports" the basic emission allowance trading program to limit acid rain, and believes that it "can be environmentally sound." Where SO_2 is concerned, "the sources are knowable and can be accurately measured," he says. That, however, is not the case with many other air pollutants, he adds, because they are numerous and difficult to quantify.

But Hawkins cautions that the only way in which the market approach can work is if EPA makes sure that a utility's emission allowances are carefully accounted for, and actual utility emissions are accurately measured. The Southern California proposals depend on a lot of engineering guesses about actual emissions of a large variety of air pollutants, he says. Under that scenario, trading in emission allowances "would be like measuring deposits and withdrawals to the nearest $10. Anyone could quickly learn to drain the bank dry."

Paul Bjorn, of the accounting and consulting firm Price Waterhouse, notes that the success of SO_2 emission allowance trading programs will depend on what actions states and public utility commissions take in regard to utilities operating under their jurisdiction. Bjorn, who is chairman of Price Waterhouse's public utility industry service group in Cleveland, says that some high-growth states, such as Florida, may require utilities to sell emission allowances only to other in-state utilities.

Ultimately, the success of any market system to limit hazardous emissions will depend on the cooperation of both federal and state regulators and on the regulated. An EPA spokesman says the federal government cannot tell state regulators how to regulate their jurisdiction. But he says that in regard to SO_2 emission allowances, EPA is encouraging local regulators not to restrict utility participation in a national trading market.

Marc Reisch

Huge growth forecast for biotech markets

The U.S. market for biotechnology products will reach nearly $3.5 billion this year, according to a report by Consulting Resources, a Lexington, Mass.-based market consulting firm. Over the next decade, various segments of this market will grow tremendously, resulting in an overall average growth rate of about 16% per year for the industry. By the start of the new decade, the market is expected to amount to more than $14.5 billion.

The biggest market segment is human therapeutic products, forecast to reach $2.25 billion in sales in 1992. Whereas sales currently are based only on just over a dozen products, most of which have been approved by the Food & Drug Administration in the past seven years, there are more than 20 awaiting review at FDA and at least another 135 in clinical trials. This market will continue to be the largest, hitting more than $9 billion by the year 2002.

U.S. biotech sales to increase about 16% per year

$ Millions	1992	1997	2002	% average annual change
Therapeutics	2250	4800	9,200	15%
Diagnostics	1050	1700	2,500	9
Agriculture	70	375	1,400	35
Specialties	95	400	1,300	30
Other[a]	10	100	250	38
TOTAL	**3475**	**7375**	**14,650**	**16%**

[a] Includes nonmedical diagnostics. **Source:** Consulting Resources Corp

Currently, products developed and marketed by biotechnology companies or sold by their larger pharmaceutical company partners include erythropoietin and granulocyte colony-stimulating factor, with combined sales of $645 million in 1991 for Amgen. Similarly, Genentech's 1991 product sales, which include tissue plasminogen activator, human growth hormone, and γ-interferon, are estimated to be about $400 million. Granulocyte-macrophage colony-stimulating factor, Immunex's first product approved for marketing in 1991, may have had sales of nearly $40 million for 1991. Biogen, Chiron, and Genentech also receive royalty income on sales of products such as α-interferon, human insulin, and hepatitis B vaccines, which have product sales of many hundred million dollars.

Diagnostics, among the first biotechnology products to be developed and to bring in revenues for many young companies, are now viewed as a more mature part of the industry. Growth in sales of diagnostics at about 9% annually over the next 10 years is expected to be below the industry average. Even at this growth rate, the market will more than double by 2002, increasing from about $1 billion in 1992 to $2.5 billion in 2002.

Growth rates will be larger for those markets starting from much smaller base levels. Agricultural biotechnology, which has lagged other areas in delivering new products, is poised for a growth rate of 35% per year. Consulting Resources still sees what it calls "limited progress," with sales rising from about $70 million in 1992 to over $1 billion by the end of the century. Growth will depend largely on more products, such as biopesticides and genetically engineered crops, receiving Environmental Protection Agency approval and making inroads into agricultural markets. Although many naturally occurring biopesticides now are marketed by several companies, only two genetically engineered biopesticides, developed by Mycogen, have passed regulatory hurdles.

Another area that may register as much as 30% growth per year is that of enzymes and specialty or fine chemicals produced by biotechnology. The market is forecast to amount to about $95 million this year and to soar to $1.3 billion in 2002. Similarly, sales of nonmedical diagnostics will record a growth of nearly 40% per year during the next 10 years.

Ann Thayer

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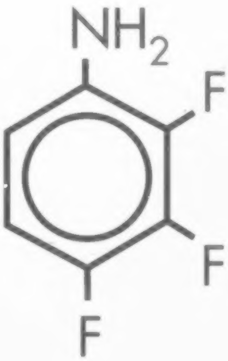

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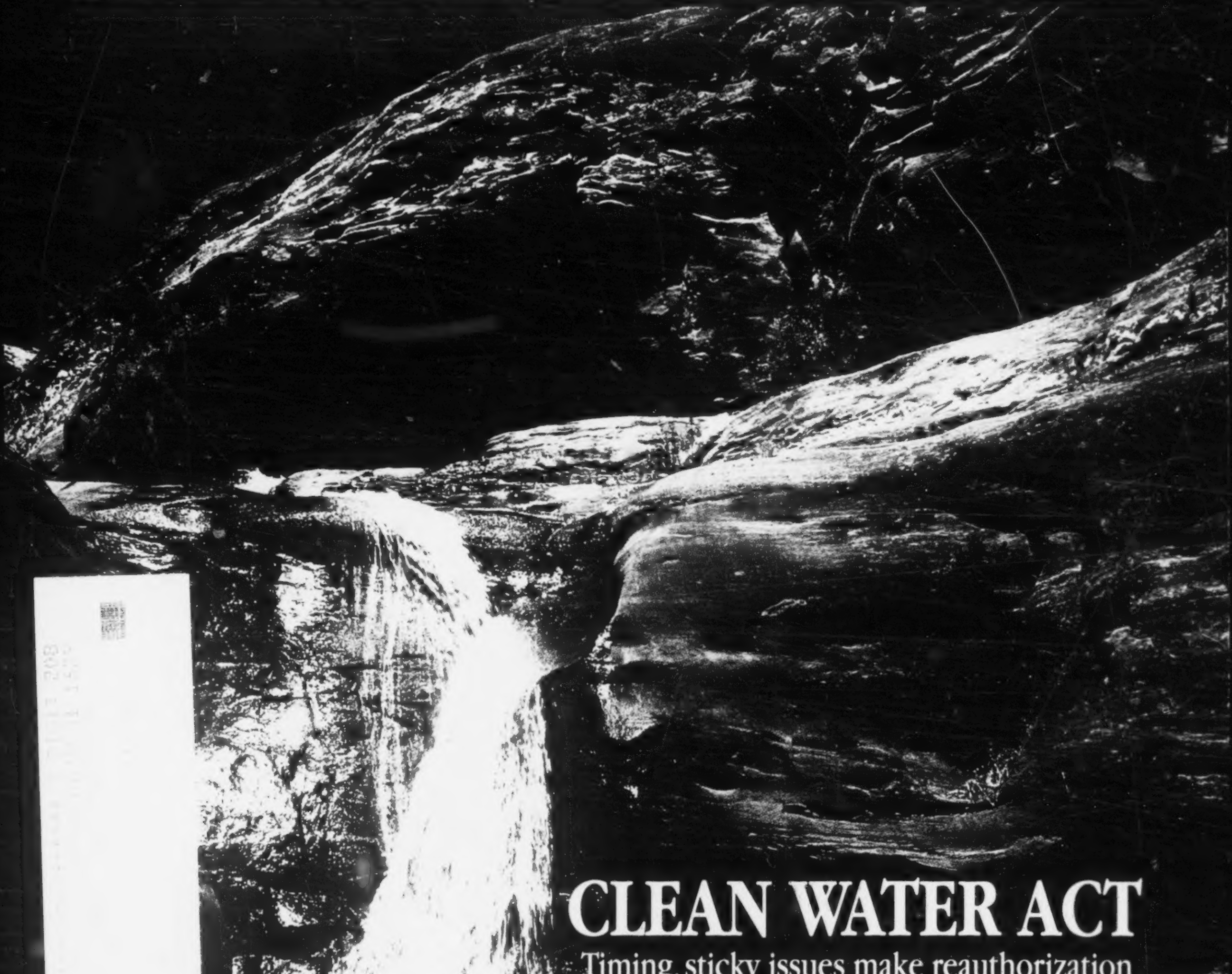
CHEMICAL & ENGINEERING NEWS

C&EN

FEBRUARY 17, 1992

CHEMICAL COMPANY EARNINGS CONTINUED THREE-YEAR DECLINE IN 1991 PAGE 10



CLEAN WATER ACT

Timing, sticky issues make reauthorization uncertain this year

Page 18

CHEMICAL & ENGINEERING NEWS
C&EN
FEBRUARY 17, 1992

NEWS OF THE WEEK

- Dow Corning releases internal documents citing problems with silicone breast implants, names new chairman and chief executive officer to tackle crisis resulting from FDA's moratorium on sale of these implants. **Page 4**
- Spacecraft Ulysses detects unexpected changes in Jovian system as it flies by Jupiter on its way to study polar regions of the Sun. **Page 5**
- President Bush moves up deadline for U.S. phaseout of CFCs to the end of 1995, four years earlier than specified by Montreal protocol. **Page 5**
- In an extension of its patent application last summer covering some 350 human brain gene sequences, NIH files second application for 2375 more, justifying its move as promoting openness in science. **Page 6**
- Hoffmann-La Roche's new licensing policy for polymerase chain reaction technology eases restrictions on diagnostic uses, and is expected to provide wider access and accelerated research into new applications. **Page 6**

COVER: Photo by Grant Heilman Photography Inc.

Volume 70, Number 7
CENEAR 70 (7) 1-56
ISSN 0009-2347

BUSINESS

Earnings of major chemical companies dropped again in the fourth quarter, marking the 10th straight quarter of decline and making 1991 another down year. **Page 10**

SCIENCE/TECHNOLOGY

Journal illustration enters computer age in *Protein Science*, which comes with a diskette containing "kinemage" interactive graphics—molecular structures and other images that users can view and manipulate in 3-D. **Page 26**

New software system for hazardous-waste-site analysis helps engineers manage, evaluate, and visualize huge quantity of data collected during waste site projects. **Page 30**

Union Carbide opens multiplastics recycling plant in New Jersey that annually will process 54 million lb of plastic film and bottles from curbside recycling programs. **Page 31**

EDUCATION

In math and science, U.S. schoolchildren are behind their counterparts in other countries, according to new study cofunded by NSF and the Department of Education. **Page 34**

ACS ELECTION

Views on ACS matters are offered by four candidates for Region II director in a special election to fill the vacancy created by Frederick Bailey's death. **Page 36**

ACS NEWS

Chemical Abstracts Service has revamped management staff in three divisions, creating two new director positions in editorial operations, reducing positions in other areas. **Page 41**

GOVERNMENT

Bipartisan rewrite of 1987 Clean Water Act, now up for renewal in Congress, will likely face rough passage because of the shift in focus it proposes—from end-of-pipe cleanup controls to entire watershed protection. **Page 18**

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

URGENT APPEAL FOR HELP

The following is an open letter submitted for publication in a number of western science publications:

We appeal from the pages of your magazine to the world scientific community to express our deep concern about a dramatic situation: The absence of hard currency completely deprives scientific institutions of Russia and other states of the former U.S.S.R. of subscriptions to foreign scientific periodicals in 1992. Our scientists [will] be totally isolated from the most important sources of scientific information. At the present time, when scientific progress is simply inconceivable without the tightest international cooperation of scientists, when the development of each field of science proceeds like a chain reaction, and when positive feedback between scientific publications and response to them is of decisive importance, the isolation of hundreds of thousands of our scientists from the outside world—inevitable under the conditions of deprivation of foreign scientific literature—will have pernicious consequences for the scientific community all over the world.

Therefore, we appeal for urgent help—for the sake of humanitarian purposes and our mutual interests—to find possibilities of continuing delivery of foreign scientific periodicals to our country in 1992 on the same scale as in 1991, or, at least, on a size sufficient to provide the 1991 subscription level for central scientific libraries of Moscow, Sanct-Petersburg, Nobosibirsk, Ecaterinburg, Vladivostok, capitals of other states of the former U.S.S.R., and libraries of largest institutes of the Russian Academy of Sciences.

We thank our foreign colleagues in advance for any manifestation of goodwill in assistance to overcome these most serious difficulties met by our scientists.

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Victor P. Maslov
Aleksandr S. Spirin
Vladimir I. Keilis-Borok
Members of the Russian Academy of Sciences

Perfluorocarbon flammability

During recent months there has been a series of letters concerning the flammability of perfluorocarbon compounds. In the original letter, Bob Dawe et al. (C&EN, June 10, 1991, page 2) reported that a supposedly inert perfluorocarbon liquid appeared to react with oxygen to produce considerably more heat and pressure than was anticipated. They also asked that suppliers of these materials reevaluate their safety data sheets.

Jay E. Taylor (C&EN, Sept. 23, 1991, page 2) indicated that an experiment containing 5% cyclohexanone in perfluorotoluene inflamed when heated to 200 °C in a 2000 psig oxygen atmosphere. Unfortunately, exact experimental details are not reported in either case.

Karl O. Christe (C&EN, Oct. 7, 1991, page 2) drew attention to the fact that Teflon will burn in pure oxygen although it is difficult to ignite. It should be noted that Teflon has an oxygen index (ASTM-D-2863-70) of 95 and thus is flammable in a mixture of 95% oxygen and 5% nitrogen at atmospheric pressure. This fact is reported in a number of places in the fire science literature, although it has little relevance to either the Dawe or Taylor reports.

In response to the Dawe et al. letter, Louis L. Ferstandig (C&EN, Aug. 5, 1991, page 2) states, "These statements should be considered along with almost 50 years of experience of saturated perfluorocarbons and chloroperfluorocarbons in oxy-

Corrections

- Jan. 13, page 36: The contact for the April 21–24 Hazardous Material Spills Conference is Technical Resources Inc., Attn: Sonja Cohen, 3202 Tower Oaks Blvd., Suite 200, Rockville, Md. 20852, phone (301) 231-5250.
- Jan. 27, page 32: The postdoctoral fellow involved in earlier University of California, Berkeley, studies was Bruce H. Weiller (not Wilder).

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Chemical Earnings Down Again in Fourth Quarter and the Year

William J. Storck,
C&EN Northeast News Bureau

Chemical earnings fell again in the fourth quarter, giving 1991 a perfect record of declining results for all four quarters. Earnings were down both at chemical companies and at oil firms and diversified corporations that also produce chemicals. As in past quarters, only pharmaceutical companies registered earnings growth.

And again, the culprit was low domestic demand, driving down chemical plant capacity utilization and prices. In addition, companies complained of higher raw material costs in the fourth quarter, which put a squeeze on profitability.

As a result, earnings fell 16% from fourth-quarter 1990 for the 28 chemical companies regularly tracked by C&EN that have reported fourth-quarter results. This marked the 10th straight quarter of declining earnings. In addition, sales for the second straight quarter were off 4% on an annual basis. For oil and diversified companies, the pattern was repeated in the quarter, only much more drastically, with earnings down 47% for chemical-producing oil companies and down 20% for diversified companies that produce chemicals. In both cases, sales fell—18% for the oil companies and 3% for diversified manufacturers. Pharmaceutical firms, however, continued their unabated growth, scoring an 18% rise in earnings and a 9% increase in sales.

The reason for the drop: The recession still has a headlock on the chemical economy; major markets for chemicals are still in the grips of the recession, holding down domestic demand for chemicals; the housing market, although showing some signs of a slight upturn at the end of the quarter, is still way down; and any possible resurgence in residential housing is more than offset by continued depressed commercial construction. The automo-

Chemical industry leaders for fourth quarter . . .

Sales

Rank 1991		$ Millions	Rank 1990
1	Dow Chemical	$ 4563.0	1
2	Monsanto	2126.0	2
3	W. R. Grace	1613.3	3
4	American Cyanamid	1334.9	5
5	Union Carbide	1151.0	4
6	Air Products	760.5	9
7	Arco Chemical	747.0	8
8	Hercules	710.0	6
9	Ethyl	659.7	11
10	Rohm & Haas	658.3	10

Earnings[a]

	$ Millions	Rank 1990
Dow Chemical	$148.0	1
W. R. Grace	79.1	2
Monsanto	66.0	22
American Cyanamid	65.9	5
Air Products	64.2	3
Ethyl	52.3	4
Great Lakes Chemical	39.7	8
Nalco Chemical	36.9	9
Morton International	34.8	10
Hercules	34.1	14

Profitability

	Earnings as % of sales	Rank 1990
International Flavors	13.5%	1
Loctite	12.7	4
Great Lakes Chemical	12.3	2
Betz Laboratories	11.2	6
Nalco Chemical	11.0	3
IMC Fertilizer	8.7	7
Air Products	8.4	9
Ethyl	7.9	8
Crompton & Knowles	7.9	11
Morton International	6.8	12

. . . and for full-year 1991

Sales

Rank 1991		$ Millions	Rank 1990
1	Dow Chemical	$18,807.0	1
2	Monsanto	8,864.0	2
3	W. R. Grace	6,049.1	3
4	American Cyanamid	4,986.2	5
5	Union Carbide	4,877.0	4
6	Air Products	2,967.0	7
7	Hercules	2,900.0	6
8	Arco Chemical	2,837.0	8
9	Rohm & Haas	2,763.0	9
10	Ethyl	2,570.0	12

Earnings[a]

	$ Millions	Rank 1990
Dow Chemical	$962.0	1
Monsanto	621.0	2
American Cyanamid	358.8	3
Air Products	241.7	6
W. R. Grace	219.2	9
Ethyl	213.7	7
International Flavors	168.7	10
Rohm & Haas	163.1	8
Great Lakes Chemical	157.5	11
Arco Chemical	151.0	4

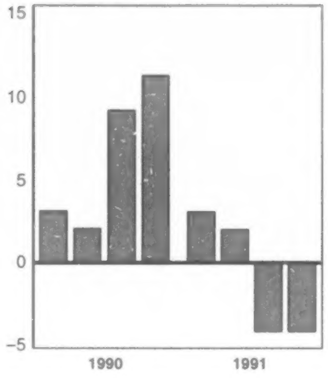
Profitability

	Earnings as % of sales	Rank 1990
International Flavors	16.6%	1
Loctite	13.6	3
Great Lakes Chemical	12.0	2
Betz Laboratories	11.3	5
Nalco Chemical	10.9	4
Ethyl	8.3	9
IMC Fertilizer	8.2	11
Air Products	8.1	10
Crompton & Knowles	8.0	12
Georgia Gulf	7.3	6
Morton International	7.3	13

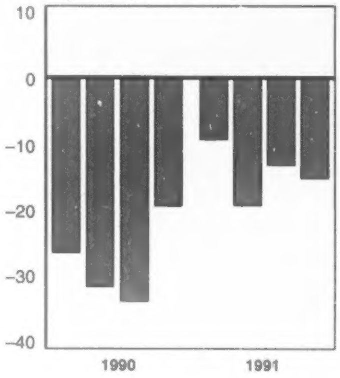
Note: Based on 30 chemical companies listed on page 12 **a** After taxes

Chemical industry 1991 fourth-quarter results

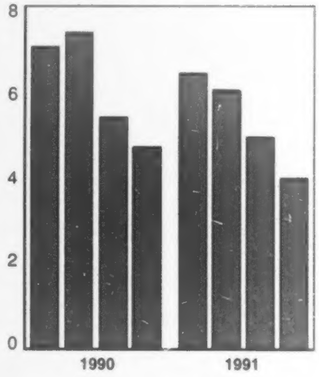
- **Sales declined 4%**
- **Earnings dropped 15%**
- **Profit margins dipped to 4.0%**
- **Production was up 1.4%**
- **But prices fell almost 2%**


Sales

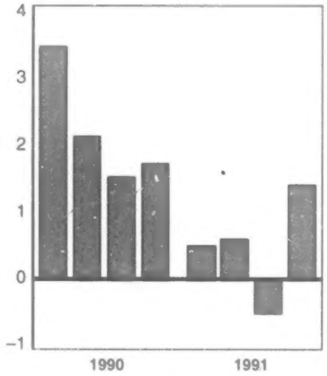
% change from year-earlier quarter


Earnings

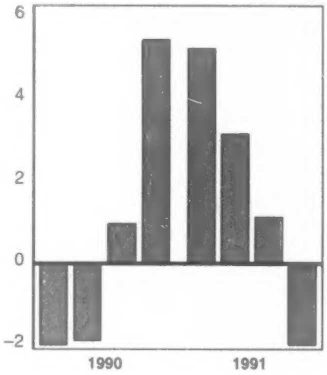
% change from year-earlier quarter


Profit margins

After-tax earnings as % of sales

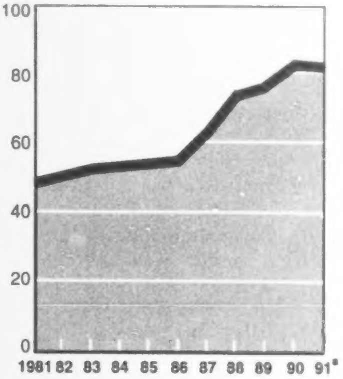

Production

% change from year-earlier quarter

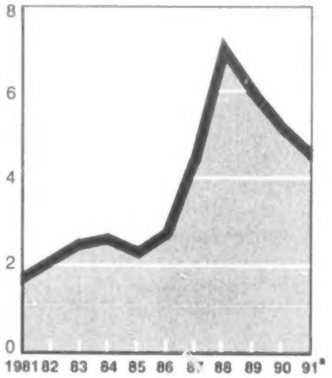

Prices

% change from year-earlier quarter

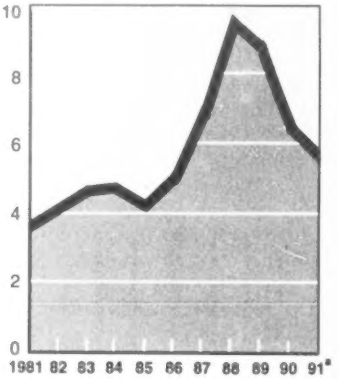
Sales decreased 1% in 1991 to $83.4 billion, as earnings fell 14% to $4.6 billion, resulting in a profit margin decline to 5.5%


Annual sales

$ Billions


Annual earnings

$ Billions


Annual profit margins

After-tax earnings as % of sales

Note: All sales, earnings, and profit margin data are based on 30 chemical companies listed on page 12. [a] C&EN estimates.

Chemical sales, earnings, profitability suffer in fourth quarter and full-year 1991

	FOURTH-QUARTER 1991						FULL-YEAR 1991					
	Sales	Earnings[a]	Change from 1990		Profit margin[b]		Sales	Earnings[a]	Change from 1990		Profit margin[b]	
	($ millions)		Sales	Earnings	1991	1990	($ millions)		Sales	Earnings	1991	1990
Air Products	$ 760.5	$ 64.2	5%	6%	8.4%	8.4%	$ 2,967.0	$ 241.7	0%	4%	8.1%	7.9%
American Cyanamid	1,334.9	65.9	18	17	4.9	5.0	4,986.2	358.8	9	14	7.2	6.9
Arco Chemical	747.0	31.0	-2	41	4.1	2.9	2,837.0	151.0	0	-42	5.3	9.3
Betz Laboratories	165.6	18.6	9	16	11.2	10.5	665.6	75.5	12	15	11.3	11.0
Cabot	384.8	16.6	-4	21	4.3	3.4	1,466.5	42.6	-7	6	2.9	2.6
Crompton & Knowles	110.0	8.7	9	19	7.9	7.2	450.2	35.9	15	20	8.0	7.7
Dow Chemical	4,563.0	148.0	-11	-46	3.2	5.3	18,807.0	962.0	-5	-30	5.1	7.0
Ethyl	659.7	52.3	-2	-10	7.9	8.6	2,570.0	213.7	2	-5	8.3	8.9
First Mississippi	132.3	1.9	12	def	1.4	def	555.3	9.5	7	91	1.7	1.0
H. B. Fuller	220.6	8.8	9	9	4.0	4.0	852.9	27.7	8	31	3.2	2.7
Georgia Gulf	182.8	12.1	-20	-36	6.6	8.3	838.3	61.5	-10	-36	7.3	10.2
B. F. Goodrich	607.4	-16.9	5	def	def	2.4	2,471.6	4.8	2	-96	0.2	4.8
W. R. Grace	1,613.3	79.1	-6	9	4.9	4.2	6,049.1	219.2	1	8	3.6	3.4
Great Lakes Chemical	321.9	39.7	11	8	12.3	12.6	1,307.6	157.5	23	12	12.0	13.2
Hercules	710.0	34.1	-14	39	4.8	3.0	2,900.0	137.5	-9	17	4.7	3.7
IMC Fertilizer	252.6	22.1	-9	-11	8.7	9.0	1,100.0	90.0	-3	2	8.2	7.8
Imcera	420.2	21.3	6	8	5.1	5.0	1,663.5	105.8	8	33	6.4	5.1
International Flavors	225.7	30.4	3	5	13.5	13.2	1,017.0	168.7	6	8	16.6	16.3
Loctite	141.5	18.0	-1	10	12.7	11.4	561.2	76.3	1	13	13.6	12.1
Lubrizol	na	na	na	na	na	11.2	na	na	na	na	na	9.5
Monsanto	2,126.0	66.0	-3	500	3.1	0.5	8,864.0	621.0	-1	27	7.0	5.4
Morton International	508.4	34.8	8	16	6.8	6.4	1,962.6	143.4	9	7	7.3	7.4
Nalco Chemical	334.6	36.9	16	6	11.0	12.2	1,237.3	134.6	16	6	10.9	11.9
Olin	594.7	10.2	-7	15	1.7	1.4	2,275.4	67.7	-12	-18	3.0	3.2
Petrolite	81.2	4.2	1	33	5.1	3.9	323.5	14.8	9	12	4.6	4.4
Quantum Chemical	636.7	-27.8	-17	def	def	1.3	2,532.4	(81.2)	-5	def	def	0.4
Rohm & Haas	658.3	29.5	-3	-20	4.5	5.4	2,763.0	163.1	-2	-21	5.9	7.3
Stepan	na	na	na	na	na	3.1	na	na	na	na	na	3.7
Union Carbide[c]	1,151.0	-41.0	-15	def	def	2.0	4,877.0	44.0	-7	-82	0.9	4.6
Witco	390.5	19.5	-6	85	5.0	2.6	1,630.5	73.5	0	8	4.5	4.2
TOTAL[d]	**$20,035.2**	**$ 788.1**	**-4%**	**-16%**	**3.9%**	**4.5%**	**$80,531.7**	**$4320.6**	**-1%**	**-14%**	**5.4%**	**6.2%**

a After-tax earnings from continuing operations, excluding nonrecurring and extraordinary items. **b** After-tax earnings as a percentage of sales. **c** Excludes results from industrial gases, now carried as a discontinued business. **d** For 28 companies reporting. **def** = deficit. **na** = not available.

bile industry, another major market for chemicals, also continues to suffer from lackluster performance.

The result was declining demand for the quarter. Government data show that although shipments of chemicals and allied products increased only about 1% for the quarter to a seasonally adjusted $74.9 billion, demand for industrial chemicals, which are largely commodities, declined more than 6% to $37.1 billion. For the full year, the Commerce Department indicates that shipments of chemicals edged up less than 1% to $288 billion, while industrial chemical shipments slipped about 3% to $152 billion.

On a poundage basis, production of chemicals and allied products for the fourth quarter increased 1.4% from the same period the year before, but output of industrial chemicals was up about 4%.

However, a slight rise in production and the resulting increase in capacity use, which remains in the 80% range, were largely ignored when it came to pricing. Selling prices of chemicals and allied products for the quarter declined almost 2% from the same period in 1990, according to Labor Department data. However, prices for industrial chemicals were off more than 7%.

For instance, at Dow Chemical, Frank P. Popoff, the company's president and chief executive officer, put a real face on the price decline for 1991 at that company when he said, "Pricing [for the full year] affected by weak industry fundamentals declined 4%, impacting profits by about $800 million."

The result, of course, was that earnings had no chance. For the 28 companies of C&EN's 30-company sample that have reported thus far, fourth-quarter earnings from continuing operations, ex-

Earnings for full year are down at oil and diversified firms, up only for pharmaceuticals

	FOURTH-QUARTER 1991						FULL-YEAR 1991					
	Sales	Earnings[a]	Change from 1990		Profit margin[b]		Sales	Earnings[a]	Change from 1990		Profit margin[b]	
	($ millions)		Sales	Earnings	1991	1990	($ millions)		Sales	Earnings	1991	1990
OIL AND GAS COMPANIES												
Amoco	$ 7,182.0	$ 200.0	−22%	−63%	2.8%	5.9%	$ 28,297.0	$ 1,531.0	−10%	−20%	5.4%	6.1%
Chevron	10,400.0	283.0	−25	−63	2.7	5.5	40,900.0	1,359.0	−4	−36	3.3	5.0
Exxon	30,870.0	1120.0	−12	−28	3.6	4.4	116,342.0	5,600.0	−1	12	4.8	4.3
Fina	859.1	21.8	−28	14	2.5	1.6	3,336.4	42.0	−16	−67	1.3	3.2
Kerr-McGee	872.1	34.8	−22	−14	4.0	3.6	3,274.1	101.6	−11	−28	3.1	3.8
Mobil	16,628.0	389.0	−14	−5	2.3	2.1	62,682.0	1,895.0	−3	−1	3.0	3.0
Occidental Petroleum	2,609.0	3.0	−25	−95	0.1	1.9	10,096.0	379.0	−12	15	3.8	2.9
Phillips Petroleum	3,370.0	48.0	−24	−84	1.4	6.6	13,260.0	257.0	−5	−61	1.9	4.7
Shell Oil	6,427.0	94.0	−21	−76	1.5	4.8	24,700.0	319.0	−7	−67	1.3	3.7
Sun Co.	2,970.0	−35.0	−25	def	def	0.5	11,930.0	70.0	−9	−69	0.6	1.7
Texaco	9,755.0	295.0	−25	−38	3.0	3.6	38,322.0	1,243.0	−8	−19	3.2	3.7
Unocal	2,769.0	31.0	−18	−72	1.1	3.3	10,895.0	127.0	−8	−59	1.2	2.6
TOTAL	**$94,711.2**	**$2484.6**	**−18%**	**−47%**	**2.6%**	**4.0%**	**$364,034.5**	**$12,923.6**	**−5%**	**−15%**	**3.6%**	**4.0%**
DIVERSIFIED MANUFACTURERS												
Allied-Signal	$ 3,004.0	$ 115.0	−4%	−7%	3.8%	3.4%	$ 11,831.0	$ 342.0	−4%	−26%	2.9%	3.7%
Du Pont	9,765.0	232.0	−12	−43	2.4	3.7	38,695.0	1,716.0	−3	−23	4.4	5.6
Eastman Kodak	5,082.0	197.0	−1	−40	3.9	6.3	19,419.0	1,050.0	3	−17	5.4	6.7
Engelhard	586.8	22.8	−11	7	3.9	3.3	2,436.4	87.9	−17	25	3.6	2.4
FMC	1,007.9	30.2	3	11	3.0	2.8	3,899.4	173.1	5	11	4.4	4.2
Ferro Corp.	265.2	12.3	−6	104	4.6	2.1	1,056.9	36.5	−6	34	3.5	2.4
3M	3,224.0	259.0	−2	−12	8.0	9.0	13,340.0	1,154.0	2	−12	8.7	10.0
NL Industries	195.6	−6.9	−14	def	def	4.6	840.3	−24.0	−7	def	def	10.3
PPG Industries	1,400.0	47.4	−7	−53	3.4	6.8	5,700.0	254.9	−5	−46	4.5	7.9
Vulcan Materials	254.8	13.2	−6	−25	5.2	6.5	1,007.5	69.0	−9	−43	6.8	10.9
TOTAL	**$19,708.4**	**$ 922.0**	**−3%**	**−20%**	**4.7%**	**5.0%**	**$ 98,225.5**	**$ 4,859.4**	**−2%**	**−22%**	**4.9%**	**6.2%**
PHARMACEUTICAL COMPANIES												
Abbott Laboratories	$ 1,886.3	$ 314.7	10%	12%	16.7%	16.4%	$ 6,876.6	$ 1,088.7	12%	13%	15.9%	15.7%
American Home Products	1,819.8	372.6	13	27	20.5	18.2	7,079.4	1,375.3	4	22	19.4	16.6
Baxter International	2,390.0	184.0	10	3	7.7	8.2	8,921.0	591.0	10	21	6.6	6.0
Bristol-Myers Squibb	2,937.2	510.0	7	20	17.4	15.6	11,159.4	2,055.5	8	18	18.4	17.0
Eli Lilly	1,572.6	311.1	9	22	19.8	17.7	5,725.7	1,314.7	10	17	23.0	21.7
Pfizer	1,850.2	195.9	4	27	10.6	8.7	6,950.0	917.1	8	14	13.2	12.5
Schering-Plough	865.6	149.0	8	14	17.2	16.3	3,615.6	645.6	9	14	17.9	17.0
Upjohn	911.4	136.4	14	18	15.0	14.5	3,401.8	537.4	13	8	15.8	16.4
Warner Lambert	1,337.0	121.0	7	15	9.0	8.5	5,059.0	558.8	8	15	11.0	10.3
TOTAL	**$15,570.1**	**$2294.7**	**9%**	**18%**	**14.7%**	**13.5%**	**$ 58,788.5**	**$ 9,084.1**	**9%**	**16%**	**15.5%**	**14.5%**

a After-tax earnings from operations excluding significant extraordinary and nonrecurring items. **b** After-tax earnings as a percentage of sales. **def** = deficit.

cluding any significant unusual items, tumbled 16% from a year earlier to a combined $788 million. Meanwhile, total sales of the 28 companies dipped 4% to $20.0 billion.

For the full year, earnings for the 28 companies fell 14% from 1990 to $4.32 billion, marking the third straight year of declining earnings in the chemical industry. Sales in 1991 also decreased, but only 1% to $80.5 billion.

And, of course, profitability continued to slide. In the fourth quarter, profit margins for the 28 chemical companies averaged 3.9%, down from 4.5% in fourth-quarter 1990 and down from almost 5.0% in the third quarter of 1991. For the full-year 1991, profitability averaged 5.4% for the companies reporting, compared with 6.2% for the previous year.

Again, commodity chemicals, and petrochemicals in particular, appeared to be the culprit. For instance, the three companies that showed losses for the quarter—B. F. Goodrich, Quantum Chemical, and Union Carbide—are heavily involved in petrochemicals or their derivatives.

Union Carbide is a good case in point. In the fourth quarter, the company had a loss from continuing operations, excluding a $46 million charge against earnings from restructuring, of $41 million. However, its industrial gases business, now carried as "discontinued operations," pending the spin-off of that unit, recorded earnings of $29 million, up 16% from the same period a year earlier.

Chemical-producing oil companies are also a good place to judge petrochemical results, and they were not at all good in the fourth quarter. At seven oil companies that have significant chemical operations—Exxon, Mobil, Occidental Petroleum, Phillips Petroleum, Shell Oil, Texaco, and Unocal—earnings from chemical operations dropped an average 45% to an aggregate $221 million from the same period a year earlier. Almost all of the companies attributed the declines to lower selling prices than were in effect during the year-earlier quarter.

Although the fourth quarter and the year did not appear to be good for the chemical industry, there may be a ray of hope for 1992: The fourth-quarter decline was not widespread through the chemical industry, but was confined largely to producers of commodity chemicals. Besides the three companies that showed losses for the fourth quarter, only five others had declines in earnings from the same period a year earlier, leaving 20 companies with earnings gains.

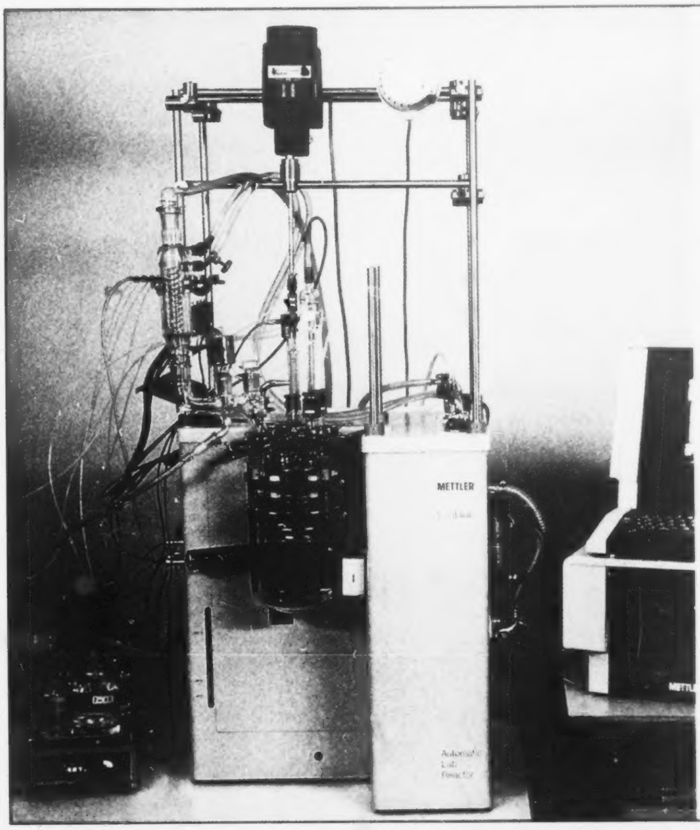
If the three companies with earnings losses are factored out, then earnings for the remaining group declined just 2% from the year-earlier quarter. If all eight of the companies with losses or declines are removed from the list, the remaining 20 chemical companies had an aggregate 27% increase in earnings on relatively flat sales. And these 20 companies had a total profit margin of 5.4%, compared with 4.3% in fourth-quarter 1990.

Thus many chemical companies are optimistic about 1992 and much of the optimism is tied both to improving economies and to restructuring and other cost-cutting measures.

At Witco, William R. Toller, chairman and chief executive officer, says, "Our continuing program of cost control and our policy of investment in modernization to improve operating efficiencies and achieve economies of scale are contributors to the bottom line. We believe 1992 will provide challenging global opportunities that our strong balance sheet will enable us to exploit."

J. Peter Grace, chairman and chief executive officer of W. R. Grace, says, "Given the continued severe recessionary times being experienced worldwide, we are encouraged by the strength of Grace's core businesses in specialty chemicals and health care. We are also confident that Grace's new worldwide business strategy announced in November 1991 will lay the groundwork for earnings growth in 1992 and beyond."

Even companies with earnings declines in the fourth quarter are moderately optimistic. Dow's Popoff says, "Pricing in 1991 was very poor and remains a challenge in 1992. However, operating rates at 85% compare favorably with the 65% rate experienced during the 1982 recession, suggesting a quick return to acceptable margins once demand recovers." ☐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C&EN

FEBRUARY 24, 1992

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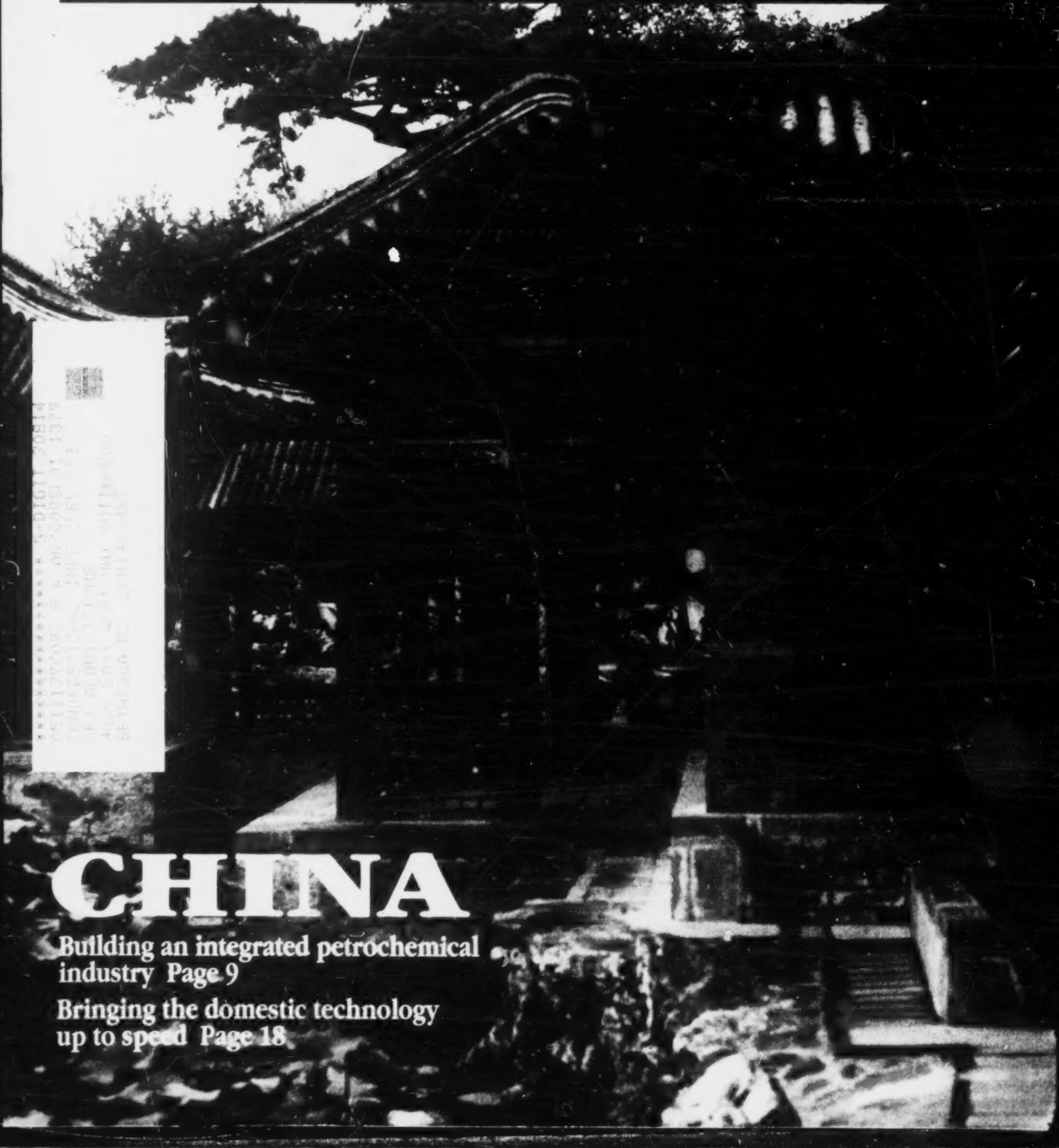

CHINA

Building an integrated petrochemical industry Page 9

Bringing the domestic technology up to speed Page 18

CHEMICAL & ENGINEERING NEWS

C&EN

FEBRUARY 24, 1992

NEWS OF THE WEEK

- OSHA issues its new process safety management standard, expected to significantly reduce catastrophic fires and explosions at chemical facilities. **Page 4**
- A number of chemists and chemical engineers are among the 79 new members and seven foreign associates elected to the National Academy of Engineering. **Page 4**
- Legislators blast forced resignation of NASA's chief, Adm. Richard Truly, as well as proposed agency budget. **Page 5**
- EPA reverses proposed ban on many uses of family of fungicides, ethylenebis(dithiocarbamates), finding they pose cancer risks much lower than previously thought. **Page 6**
- Comprehensive energy bill passes Senate by vote of 94 to 4; final bill lacks two most contentious provisions, which would have opened the Alaska National Wildlife Refuge to oil drilling and mandated fuel economy standards for autos and trucks. **Page 6**

COVER: Pavilion at Imperial Summer Palace near Beijing. Photo by C&EN's Joseph Haggin

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CENEAR 70 (8) 1–60
ISSN 0009-2347

GOVERNMENT

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International alliance of legislators and environmental activists pressure Administration to change its carbon dioxide emissions policy. **Page 16**

SCIENCE/TECHNOLOGY

Development of Chinese petrochemical industry has accelerated as country seeks to bring chemical industry technology up to international standards. **Page 18**

Synthetic self-replicating molecules are taken one step closer to mimicking life in new study that may shed light on evolution at the molecular level. **Page 21**

General catalytic method gives single enantiomers of α-amino acids from cheap achiral starting material. **Page 23**

Genetic evolution differs in separate regions of the genome according to study that compares nucleotide sequences in mouse, human, and rabbit genomes. **Page 27**

ACS NEWS

First set of 1992 PRF grants has been approved, committing $5.34 million of the $14.7 million authorized for this year. **Page 32**

Recruitment of more minorities into the chemical sciences is the goal of an implementation task force set up recently by the society. **Page 40**

BUSINESS

China's Sinopec is poised to play a big role in the global petrochemical market following modernization of its facilities at home and expansion of its operations overseas. Page 9

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1155—16th St., N.W., Washington, D.C. 20036

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AMERICAN CHEMICAL SOCIETY
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Modernizing p-chem labs

Upon reading the report (C&EN, Jan. 6, page 29) that describes the physical chemistry project (mid-Atlantic consortium) I was once more depressed by the apparent equating of the use of state-of-the-art "black boxes" with methods for teaching the fundamentals of physical chemistry laboratory operations. Upgrading laboratory programs seems to be identified with the exposure of students to highly integrated, computer-based, complex devices that were primarily developed by apparatus manufacturing companies for analytical services.

Apparently I am old-fashioned. I am of the opinion that p-chem labs should provide students with hands-on experience on methods for characterizing materials: measuring their physical properties, such as heats of formation, molecular structure, absorption and emission spectra, dipole moments, surface tension, viscosity, thermal conductivity, diffusion, and so on; the nature of transformations, such as phase changes, coexistence conditions, adsorption, electrode reactions, and the like; and rates of interconversions that incorporate kinetics, photochemistry, and nuclear processes.

Of course, there isn't enough time to cover all of the above. Hence, in my lexicon, upgrading should result in a return to more lab hours devoted by students to experiments that embody basic principles of physical measurements, not by bringing into the laboratory devices that require a minimum amount of training to push buttons on a computer-controlled, highly integrated device that prints out predetermined answers.

Current activity in physical chemistry research is way beyond what can be illustrated in the first laboratory course. Demonstration of current activity is best reserved for carefully illustrated lectures that build on the fundamental principles uncovered during the direct involvement of students with well-designed experiments. Such lectures can best show how these principles were utilized and integrated into the black boxes that command high prices.

Consider two examples. To tell students that they are recording an absorption spectrum with a Fourier transform infrared instrument is false; that device records the Fourier transform of the light that enters the interferometer through a wide aperture. An honest teacher must then decide whether he or she wishes to emphasize principles of optics or the infrared properties of materials. When the teacher decides on the latter, the FTIR becomes a black box. Then an honest teacher must decide whether to tell students that the ratio of intensities of the split rotational lines in the HCl fundamental band gives the wrong 35/37 isotope ratio, and to note the effect of pressuring the HCl with added argon.

The C&EN report reads as though lasers are the hottest item in the arsenal of physical chemistry operations. About 25 years ago there was much preoccupation with chemical lasers, and some very interesting chemistry evolved as a consequence. Regrettably, the indicated use of lasers in 1992 appears to be restricted to treating them merely as super light sources.

I ask why—and cannot escape the conclusion that part of the pressure to bring new toys into the laboratory is an attempt to beguile students and give them a bit of "gee whiz" for the trouble they experience by participating in the course.

Simon H. Bauer
Professor of Physical Chemistry
Baker Laboratory of Chemistry
Cornell University

Heat release phenomenon

One book that was reviewed on cold fusion (C&EN, Jan. 13, page 28) seemed to suggest that the excess heat release phenomenon observed in some experiments may be real, and partly for that reason some workers remain hopeful of a positive outcome. As a sideline observer of this spectacle, I have waited and listened—long and patiently, but in vain—to hear the admission that electrolyzing

Correction

- Jan. 20, page 5: At room temperature and atmospheric pressure, graphite is a more stable phase of carbon than diamond. However, at pressures of 2 gigapascals and above, diamond is the more stable phase.

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China's Sinopec Sets Sights on International Petrochemical Market

■ ***Consolidation at home and expansion abroad have given Sinopec a sound base for its move into the global arena***

Joseph Haggin, C&EN Chicago

The dominant organization in the Chinese petrochemical industry is China Petro-Chemical Corp. (Sinopec). Since 1983, Sinopec has managed to organize China's oil and gas companies into an unusually profitable unit. Sinopec is now expanding its operations overseas, modernizing its facilities at home, and preparing to play a major role in international petrochemical markets. How successful Sinopec's plans turn out to be probably will depend to a large extent on future economic and industrial reforms that are in the works.

Not surprisingly, one of the biggest Sinopec enthusiasts is its president, Sheng Huaren, who has been presiding over the vast conglomerate since 1990, when he replaced former president Chen Jinhua. Chen was moved up to become director of the State Commission for Restructuring the Economic System. The success of Sinopec may have been something of a model for industrial planners in China, who continue their efforts at restructuring.

Last September, Sheng told a plenary session of the International Conference & Exhibition on Petroleum Refining & Petrochemical Processing (Interpec China 91) held in Beijing that Sinopec had every intention of becoming an international player in the petrochemical business. To him that meant consolidating production at home and expanding abroad wherever the profits would lead. Like most Chinese industrial leaders, Sheng is keenly aware of the importance to China of foreign credits. Sinopec is also a main avenue for the introduction of high-tech science and engineering into China and a key channel for technical expertise that China is now avidly seeking (see page 18).

When the communists took over the mainland in 1949, China had only several small oil refineries, and more than 90% of the crude oil processed was imported. Sheng says development of the Daqing oil field provided self-sufficiency in oil for China by 1963. This prompted further exploration and development, which was stalled by the internal problems associated with the so-called Great Leap Forward and the Cultural Revolution conducted by Mao Ze-dong.

Following Mao's death, reform was speeded up and numerous chemical manufacturing complexes were started and operated independently with little coordination. The chemical industry was almost exclusively focused on domestic production.

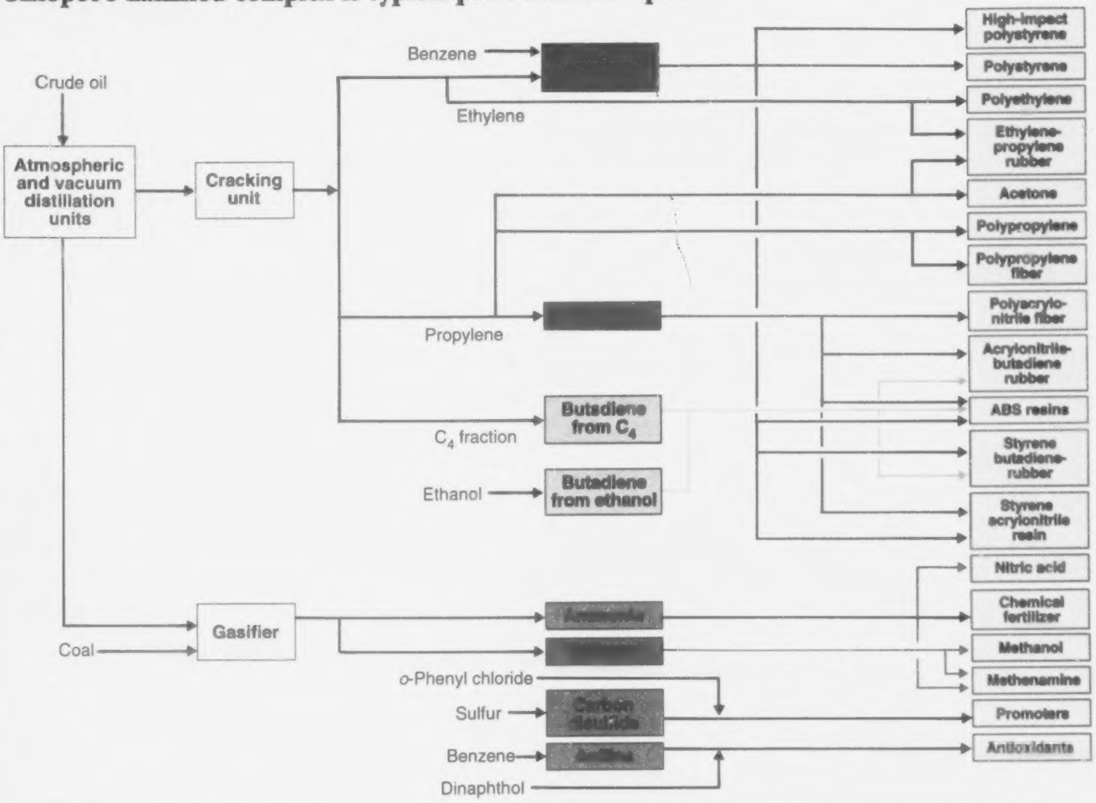
Sinopec was founded in July 1983 with domestic capital of about $3.9 billion at current exchange rates. It is a state-operated corporation reporting directly to the State Council of the government. The principal business of Sinopec is oil refining and petrochemical production from crude oil and gas. The corporation also manages Sino-foreign investment enterprises in petroleum and petrochemicals at home and abroad.

As of the beginning of this year, Sinopec controls more than 70 subsidiaries, which operate 38 refineries, 21 basic organic chemical facilities, 15 synthetic fiber facilities, five synthetic rubber plants, three synthetic resin plants, 13 chemical fertilizer facilities, five construction companies, seven research and design institutes, and six trade and sales organizations. Total work force is about 830,000 people, including 75,000 scientists and engineers and about 200,000 people in the sales force. The corporation has branch offices in Japan, the U.S., Germany, Thailand, Ecuador, and Hong Kong.

Sinopec has long list of major subsidiaries

Yanshan Petrochemical Corp.
Tianjin Petrochemical Co.
Fushun Petrochemical Co.
Jinzhou Petrochemical Co.
Dalian Petrochemical Co.
Liaoyang Petrochemical Fiber Co.
Gaoqiao Petrochemical Co.
Jinling Petrochemical Co.
Yangzi Petrochemical Co.
Qilu Petrochemical Co.
Baling Petrochemical Co.
Maoming Petroleum Industry Co.
Lanzhou Chemical Industry Co.
Daqing General Petrochemical Works
Shanghai General Petrochemical Works
Lanzhou Petroleum Processing & Petrochemical Complex
Jinxi Petroleum Processing & Chemical Complex
Zhenhai General Petrochemical Works
Anqing General Petrochemical Works
Guangzhou General Petrochemical Works
Urumqi General Petrochemical Works
Shijiazhuang Refinery
Cangzhou Refinery
Qianguo Refinery
Harbin Refinery
Lunyuan Refinery
Fujian Refinery
Jiujiang Refinery
Jinan Refinery
Luoyang Refinery
Wuhan Petrochemical Works
Jingmen Refinery
Hubei Chemical Fertilizer Plant
Sichuan Vinylon Plant
Ningxia Chemical Works
Dushanzi Refinery
Yiping Chemical Works
Changcheng Premium-Grade Lube Oil Co.

Sinopec's Lanzhou complex is typical petrochemical operation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Cracking unit
Benzene
Ethylene
Propylene
C_4 fraction
Ethanol
Butadiene from C_4
Butadiene from ethanol
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Ammonia
o-Phenyl chloride
Sulfur
Carbon disulfide
Benzene
Aniline
Dinaphthol
High-impact polystyrene
Polystyrene
Polyethylene
Ethylene-propylene rubber
Acetone
Polypropylene
Polypropylene fiber
Polyacrylonitrile fiber
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Promoters
Antioxidants

By its own estimate, Sinopec processes about 90% of China's crude oil, gas, and petrochemical products. At the end of 1990, the fixed assets of Sinopec were valued at $17 billion. Sales revenue was about $12 billion, with taxable profits estimated to be $3 billion.

As an indicator of the growth of Sinopec since the reforms began in 1983, Sheng notes that, between 1983 and 1990, Sinopec put on stream four 300,000 metric-ton-per-year ethylene plants at Daqing (Heilongjiang province), Qilu (Shandong province), Yangtze (Jiangsu province), and Jinshan (Shanghai). Several others are now in various stages of construction. In addition, three 300,000 metric-ton-per-year ammonia plants and three 520,000 metric-ton-per-year urea plants were built at Zhenhai (Zhejiang), Urumqi (Xinjiang), and Ningxia.

Most of the developments in the petrochemical, and most other industries, correspond to a series of five-year plans promulgated by government planners. The eighth five-year plan began in 1990. For Sinopec, the government has stipulated that total ethylene production be increased to 2.3 million metric tons per year in 1995 and then to 3 million by 2000. This means at least 18 new major projects will be financed within the corporation or via joint ventures. Included are eight ethylene projects, three chemical fiber projects, three large fertilizer projects, and three deep-catalytic-cracking projects for the refineries.

All this production entails a large sales and promotional effort, and a corresponding marketing organization has been developed to suit China's planned economy at home and potential free market customers abroad. This means marketing about 1500 different products, often to customers who are not familiar with them. Private conversations with several Sinopec marketing people strongly suggest that much of Sinopec's marketing effort would be considered technical service elsewhere.

Sinopec's growing foreign trade is not yet a challenge to most international producers. However, it is significant. In 1990 Sinopec exported about 6 million metric tons of various oil and petrochemical products with a value of $1.4 billion. The total import volume was valued at about $354 million, of which $110 million was spent on imported technology and equipment. Imported chemical raw materials cost China $152 million in 1990, and $49 million was spent on metals and nonmetals. In 1990, Sinopec signed loan agreements totaling about $80 million. These will help finance 11 joint-venture projects, including the Fushun acrylonitrile plant.

Sheng also reported on the investment in R&D. Present plans call for heavy investment in 10 major areas:

- New technology for the deep processing of heavy oil for increased yields of middle distillates.
- Higher quality feedstocks for olefins and aromatics.
- New technology for olefins and aromatics production.

- Improved technology for making fine chemicals with high added value.
- New technology for catalysts and additives.
- New processing for and applications of plastics.
- A new attack on corrosion prevention, plant safety, and environmental protection.
- Improved instrumentation, simulation, and control.
- Development of new petrochemical materials.
- Development of a new high-tech R&D effort to extend into the next century.

The efforts of Sinopec have already shown some effects abroad. On Jan. 5, Liu Mingyu, chairman of the board and president of China National Chemical Construction Co. (CNCCC), China's major overseas contractor, announced a five-part plan to increase business overseas in 1992. CNCCC will begin active exploration of markets in the Middle East, Southeast Asia, Africa, Latin America, and Eastern Europe, in addition to the Commonwealth of Independent States. The company will open offices in Western Europe, Southeast Asia, and the Middle East and expand existing offices in New York, Tokyo, Bangkok, Paris, Hong Kong, and Dacca, Bangladesh. New partners will be sought for joint ventures and the company will establish more subsidiaries at home. It also intends to establish closer cooperation with foreign trade companies in an effort to raise the export business to at least $100 million in 1995.

China Petrochemical International, a subsidiary of Sinopec known as Sinopec International, announced its immediate plans on Jan. 18. Feng Shikai, vice general manager of the firm, said his company has mapped out its market strategy for the next five years. Targets include importing technology and equipment to build a new ethylene plant (300,000 metric tons per year) at Maoming (Guandong). The company also will aid in transforming an ethylene plant at the Yanshan Petrochemical Corp. (another Sinopec subsidiary) from its present capacity of 300,000 metric tons per year to 450,000. This will be the largest ethylene plant in China. By the end of 1995, says Feng, Sinopec International will be involved in the construction of six new ethylene plants, three polyethylene plants, and three ammonia plants.

The key exports in Sinopec International's plans are minimally processed oil, petroleum coke, paraffin waxes, synthetic rubber, and synthetic resins. Deng Wenshen, deputy general manager of marketing research, says one of the biggest exports in the future is expected to be methyl *tert*-butyl ether (MTBE) for use as a gasoline additive. He projects that this year's market for MTBE in Japan will be 400,000 metric tons, and in the U.S. 2 million tons.

In looking at the development of China's chemical industry, it is apparent that most of it is based on the technology of 1960, with incremental improvements. Since 1983, with the onset of political and economic reforms, Sinopec has tried to bring the industry up to speed not only by enlarging capacity but also by acquiring state-of-the-art technology. On the day after Christmas, Sheng told a national conference of petrochemical managers that Sinopec had spent $750 million for imported technology and equipment in 1991. This, he said, represents the best investment that can be made over and above the maintenance of political stability inside China. ☐

Sinopec produces bulk of China's petrochemicals

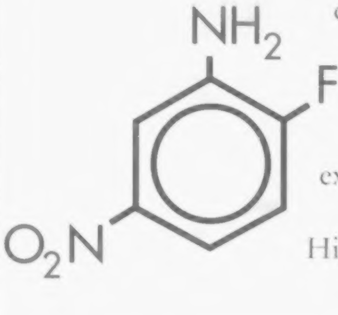
Materials	Annual capacity (millions of metric tons)	% of China's total capacity
Crude-oil refining	131	90.3%
Total downstream petrochemicals	56.13	91.4
Ethylene	1.82	87.9
Downstream products		
Plastics	1.96	
Synthetic fiber monomers	1.09	
Synthetic fiber polymers	0.52	
Synthetic rubber	0.25	
Ammonia	3.34	
Urea	5.26	
Other organic feedstocks	3.20	

Source: Sinopec

Hoechst offers out of R+D:

2-Fluoro-5-nitroaniline

now available in
lab quantities
in pilot plant
quantities



another
example of
Hoechst
High Chem

Hoechst Celanese Corp.
Fine Chemicals Division
P.O. Box 1026
Charlotte, NC 28 201-1026
USA
Fax 704-559-6153
Tel 800-242-6222

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Germany
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CIRCLE 23 ON READER SERVICE CARD

First Set of 1992 PRF Grants Approved

At its December meeting the ACS Board of Directors approved 185 new or continuing ACS-PRF grants for fundamental research or scientific education, plus 31 supplements to existing grants for Summer Research Fellowships to benefit faculty from four-year colleges, and 58 undergraduate supplements to new AC and G grants to universities. These grants, committing $5,337,723 of the $14.7 million authorized for 1992, were recommended from the 617 proposals considered by the PRF Advisory Board in November of 1991.

The last meeting of the PRF Advisory Board to recommend 1992 grants is scheduled for May. Proposals for 1993 funding will be accepted at least through June for the November advisory board meeting. Information and application materials may be obtained from the Petroleum Research Fund, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036, or by calling (202) 872-4481.

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type AC)

Jeanette Adams, Emory U. Fragmentation Dynamics of Small Amide Radical Cations. $63,000

Thomas A. Albright, U of Houston. Reactions and Rearrangements in Organometallic and Solid-State Materials. $40,000

John L. Anderson, Frederick Lanni, Carnegie Mellon U. Diffusion, Flow, and Partitioning in Gels. $40,000

Roger N. Anderson, Columbia U. Sequence Stratigraphic Interpretation and Stratigraphic Modeling Study of Two Neogene Passive Margins. $40,000

Rutherford Aris, U of Minnesota. Reactions in Continuous Mixtures. $43,000

Paul A. Baker, Duke U. Burial Diagenesis of Dolomite—an Experimental and Field Study. $40,000

Jay L. Banner, U of Texas, Austin. Marine Burial Diagenesis of Carbonate Platforms and Secular Variations in Late-Devonian Seawater. $43,000

Philip R. Brooks, Rice U. How Does Molecular Orientation Affect Electron Transfer? $43,000

David J. Burdige, Old Dominion U. Coupled Nonlinear Models of Diagenetic Processes in Marine Sediments. $43,000

Robert M. Bustin, U of British Columbia. Direct Chemical Characterization of Kerogen Using Electron Microprobe and Micro-FTIR Techniques. $40,000

Hugo S. Caram, Lehigh U. A Random Walk Model for the Motion of Granular Solids. $40,000

Bernard D. Coleman, Rutgers U. Rheology of Cold Drawing of Polymeric Materials. $40,000

Robert M. Corn, U of Wisconsin, Madison. Second Harmonic Generation Studies of Molecular Orientation at the Interface of Two Immiscible Electrolyte Solutions. $39,995

James A. Cowan, Ohio State U. The Chemistry of Metal Cofactors in DNA-Processing Enzymes. $40,000

Jeannie L. Darby, U of California, Davis. Biodegradation of Hydrocarbon in Aquifers: Effects on Permeability and Relationship to Grain Size. $43,000

E. James Davis, U of Washington. The Spectroscopy of Hydrocarbon Microparticles. $40,000

Joseph P. Dinnocenzo, U of Rochester. Odd-Electron Substitution Reactions. $40,000

Steven R. Emerson, U of Washington. Early Diagenesis of Vanadium in Marine Sediments. $43,000

Thomas P. Fehlner, U of Notre Dame. Clusters as Substituents: a New Route to High-Nuclearity Clusters and Designed Materials. $43,000

Udo Fehn, U of Rochester. Systematics of ^{129}I in Marine Sediments. $40,500

John P. Ferraris, U of Texas, Dallas. Design and Synthesis of Low-Bandgap Polymers. $43,000

Thomas C. Flood, U of Southern California. General Acid/Base Catalysis of Reactions at Metal Centers. $40,000

William C. Forsman, U of Pennsylvania. Polymers at the Solid-Liquid Interface in Random Porous Media: Studies by Small-Angle Neutron Scattering. $40,000

Eiichi Fukushima, Lovelace Medical Foundation. Interphase Boundaries of Multiphase Flows in Porous Media: an NMR Imaging Study. $40,000

Phillip H. Geil, U of Illinois, Urbana-Champaign. Transitions in Polyhydroxybenzoic Acid—Mechanisms and "Liquid Crystal" Structures. $40,000

John W. Geissman, U of New Mexico. Paleomagnetic, Rock Magnetic, and Stable Isotope Investigation of Late Paleozoic Remagnetization of Precambrian Basement and Immediately Overlying Strata, Central and Southern Rocky Mountains. $43,000

Peyman Givi, State U of New York, Buffalo. Mixing and Reaction in Turbulent Flows. $43,000

Alan S. Goldman, Rutgers U. Alkane Carbonylation and Aldehyde Decarbonylation Catalyzed by Low-Valent Transition-Metal Complexes. $40,000

Robert J. Gordon, U of Illinois, Chicago. Dynamics of Oxygen Atoms on Multiple Potential Energy Surfaces. $40,000

Harvey A. Gould, Clark U. Computer Simulation Studies of the Structure and Dynamics of Model Atomic Glasses. $40,000

Phillip L. Gould, U of Connecticut. Experiments in Ultracold Collisions. $40,000

Gordon W. Gribble, Dartmouth C. Novel Syntheses of Highly Strained Organic Molecules. $40,000

Gregory L. Griffin, Louisiana State U. Aerosol Synthesis of Aluminum Nitride Preceramic Powders via Chemical Precursors. $40,000

H. S. Gutowsky, U of Illinois, Urbana-Champaign. High-Resolution Spectroscopy of Transient Species. $43,000

William W. Hay, U of Colorado. The Significance of Geology, Climate, and Local Relief on the Load of Rivers. $43,000

Paul L. Heller, U of Wyoming. The Stratigraphic Record of Alluvial Response to Base-Level Changes: Eocene Fan-Delta Sequences of Southeastern Ebro Basin, Spain. $43,000

Teresa E. Jordan, Cornell U. Seismic Stratigraphy of the Bermejo Foreland Basin, Argentina. $40,000

Susan M. Kauzlarich, U of California, Davis. Synthesis and Characterization of Novel Layered Compounds. $40,000

William C. Kelly, U of Michigan. Geologic and Thermochemical History of the White Pine District, Keweenaw Rift, Northern Michigan. $14,373

Stephen E. Kesler, U of Michigan. Cl/Br and δ^{18}O-δD Analyses of MVT-Forming Fluid Inclusion Brines, Southern and Central Appalachians. $40,000

Douglas J. Klein, William A. Seitz, Texas A&M U, Galveston. Comprehensive Generation and Partial Characterization of "Large" Elemental Carbon Cages. $40,000

Joel Koplik, City U of New York, City C. Hydrodynamic Dispersion in Flow in Porous Media. $40,000

Sonja Krause, Rensselaer Polytechnic Inst. Studies of Pore Structure in Polymeric Reverse Osmosis and Ultrafiltration Membranes Using SAXS, SANS, and Low-Angle Light Scattering. $40,000

Stephen G. Kukolich, U of Arizona. Microwave Measurements of Structures and Quadrupole Coupling for Transition-Metal Complexes. $40,000

Mark Lautens, U of Toronto. Ring-Opening Reactions of Oxabicyclic Compounds. $40,000

Marsha I. Lester, U of Pennsylvania. Determination of Realistic Intermolecular Potential Energy Surfaces for OH(X $^2\Pi$, A $^2\Sigma^+$) + Ar. $40,000

Dennis L. Lichtenberger, U of Arizona. Electronic Structure and Bond Energy Trends in Metal-Carbon and Metal-Silicon Chemistry. $43,000

Katja Lindenberg, U of California, San Diego. Soliton Models of Proton/Energy Transport Mechanisms in Cyclodextrin. $40,000

Kenneth B. Lipkowitz, Indiana U-Purdue U, Indianapolis. Enantiodiscrimination on Chiral Polymers. $40,000

Timothy P. Lodge, U of Minnesota. Polymer Diffusion in Microstructured Media. $20,000

Kyger C. Lohmann, U of Michigan. Multitracer Analysis of Diagenetically Altered Corals in the Pleistocene Key Largo Limestone Implications for ^{230}Th Ages of Corals. $43,000

Austin Long, U of Arizona. Stable Chlorine Isotopes as Indicators of Source and/or Evolution of Basin Brine. $40,000

William G. Madden, Wayne State U. A Theoretical Framework for the Adsorption of Fluids into Disordered Media. $43,000

Olivier R. Martin, State U of New York, Binghamton. Stereoselective Synthesis of *C*-Glycosyl Compounds by way of Intramolecular Reactions of 2-Organosilyl Glycosides. $40,000

Richard M. Martin, U of California, Santa Barbara. Vibrational Enhancement of the Adsorption of Nitric Oxide and Formaldehyde on Metal and Semiconductor Surfaces. $40,000

James M. Mayer, U of Washington. Radical Reactions of Transition-Metal Oxo Complexes. $43,000

Michael J. McKelvy, William S. Glaunsinger, Arizona State U. Atomic-Level Imaging of Dynamic Staging Processes. $40,000

Michael O. McWilliams, Stanford U. Fission Track and ^{40}Ar/^{39}Ar Investigation of Metamorphism and Uplift in the Franciscan Subduction Complex, California. $40,000

Josef Michl, U of Colorado. A Molecular Carpet. $40,000

Glenn L. Millhauser, U of California, Santa Cruz. Development of Electron Overhauser Enhancement Spectroscopy (EOESY) as a New Technique for Revealing Peptide Geometry. $40,000

Gautam Mitra, U of Rochester. Growth History of a Fault Propagation Fold, Canyon Range, Utah. $40,000

Almeria Natansohn, Queen's U. Compatibilization of Polymer Blends by Charge-Transfer Interactions: an NMR Investigation. $40,000

Keith A. Nelson, Massachusetts Inst. of Technology. Picosecond-Microsecond Time-Resolved Spectroscopy of 1 MHz–100 GHz Coherent Acoustic Waves in Viscoelastic Fluids. $40,000

Ronald E. Noftle, Wake Forest U. Preparation, Polymerization, and Electrochemical Properties of Novel Thiophenes with Highly Electron-Withdrawing Groups in the 3-Position. $40,000

H. Daniel Ou-Yang, Lehigh U. Light-Scattering Studies of Polymer Adsorption on Colloidal Surfaces: Phase Transition and Kinetics. $43,000

John Parnell, Queen's U. Studies of Hydrocarbon Migration Using Bitumen-Mineral Relationship. $40,000

Rinaldo Poli, U of Maryland. The Energetic Effect of Unpaired Electrons in Organometallic Compounds. $43,000

Raj Rajagopalan, U of Houston. Interaction Forces in Dense Fluids and Colloidal Dispersions: the Inverse Problem. $43,000

Andrzej Rajca, Kansas State U. π-Conjugated Triplet Diradical Anions. $40,000

Richard Robson, U of Melbourne. New Infinite 2-D and 3-D Frameworks. $40,000

Dean M. Roddick, U of Wyoming. Heterolytic Activation of H–H and C–H Bonds. $43,000

Juergen Schieber, U of Texas, Arlington. Shale Microfabrics and Their Relationship to Mesofabrics and Sedimentary Environments: a Case Study of the Newland Formation, Montana. $35,000

John M. Sharp Jr., U of Texas, Austin. Fluid and Heat Flow in Sedimentary Basins: Geologic and Hydrologic Constraints on a Thermal Anomaly in South Texas, Northern Gulf of Mexico Basin. $39,855

Duncan F. Sibley, Michigan State U. Dolomite Crystal Growth Rate. $43,000

Scott McN. Sieburth, State U of New York, Stony Brook. The Vinylsilane Diels–Alder Reaction. $43,000

Peter E. Siska, U of Pittsburgh. Energy Disposal and Dynamics in Penning Ionization Reactions. $40,000

Gopalan Srinivasan, Oakland U. Magnetic Ordering in Amorphous Transition-Metal Oxides. $40,000

Eric M. Stuve, U of Washington. Ex-situ Studies of the Electrochemical Double Layer. $40,000

William C. Stwalley, U of Iowa. Autoionization of Doubly Excited States of Alkali Metal Diatomics. $40,000

Michael R. Topp, U of Pennsylvania. Multiphoton Studies of Ionization in Molecular Clusters. $40,000

Sukant K. Tripathy, U of Massachusetts, Lowell. Novel Photocrosslinked Nonlinear Optical Polymers and Related Electrooptic Devices. $43,000

Martin T. Vala Jr., U of Florida. Spectroscopic Studies of Aromatic Cations. $43,000

Christopher Viney, U of Washington. From Natural Silk Secretions to High-Performance Fibers. $50,000

David H. Waldeck, U of Pittsburgh. Experimental Studies of Encounter Pair Dynamics for a Model Bimolecular Reaction. $43,000

Richard G. Weiss, Georgetown U. Long-Range Photoinduced Electron-Transfer Processes Studied in Solid Phases of *n*-Alkanes. $40,000

Emil H. White, Johns Hopkins U. Trapping of Metastable Carbonium Ions To Yield Novel and Useful Products under Conditions of Kinetic Control. $43,000

Gary A. Williams, U of California, Los Angeles. Surface and Bulk Tortuosity of Porous Ceramics Near the Percolation Threshold. $43,000

Andrew Wojcicki, Ohio State U. Transition-Metal Oxo-Hydrido and Imido-Hydrido Complexes. Coupled Ligand Transfer Reactions to Unsaturated Substrates. $63,000

L. Keith Woo, Iowa State U. Coordination and Organometallic Chemistry of Metalloporphyrins. $40,000

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type B)

Brian J. Bozlee, Whitman C. Surface-Enhanced Raman Spectroscopy of Metal Colloids. $20,000

Michael P. Castellani, Marshall U. Synthesis and Characterization of Pentaphenylcyclopentadienyl Stabilized Paramagnetic Transition-Metal Complexes. $20,000

John D. Cooper, California State U, Fullerton. Sheets or Shingles? A Case Study on the Origin of Laterally Extensive Sandstones of an Early Stage Continental Margin. $20,000

Dru Germanoski, Lafayette C. Reevaluation of Relationships between Bar-Forming Processes and Sedimentary Structures in Gravel-Bed Braided Rivers. $20,000

Scott C. Hartsel, U of Wisconsin, Eau Claire. Selectivity and Structure of Amphotericin B Channels. $20,000

Bert E. Holmes, Arkansas C. Kinetics and Dynamics of Unimolecular and Bimolecular Reactions of Halocarbons. $20,000

Daniel M. Ketcha, Wright State U. Synthesis of Natural Products Using *N*-Protected Pyrroles. $20,000

Cheryl L. Klein, Xavier U of Louisiana. High-Pressure X-Ray Diffraction Studies of Organic Molecules with Intermolecular Hydrogen Bonds. $20,000

Kevin W. McLaughlin, U of Southern Indiana. Molecular Structure Distributions for Polymers Synthesized with Heterogeneous Ziegler–Natta Catalysts. $20,000

Roger S. Rowlett, Colgate U. Structure and Catalytic Mechanism of Plant Carbonic Anhydrase. $20,000

Charles D. Schaeffer Jr., Elizabethtown C. Dimethylphosphaneborane Chemistry. $20,000

Lawrence C. Thomas, Seattle U. Quantitative Dual-Isotope Comparisons of Reaction Product Abundances by GC-MS. $20,000

Larry C. Thompson, U of Minnesota, Duluth. Possible Geometric Isomerism in Adducts of the Rare Earth β-Diketonates. $20,000

Hal Van Ryswyk, Harvey Mudd C. Electrochemical Studies of Ion Penetration through Self-Assembling Monolayers. $20,000

Stephen R. Wassall, Indiana U-Purdue U, Indianapolis. Deuterium Nuclear Magnetic Resonance Studies of Positional Isomers of an Unsaturated Phospholipid Bilayer. $20,000

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type G)

Leslie H. Allen, U of Illinois, Urbana-Champaign. Growth and Characterization of Si, SiGe, and Carbon Crystals by Low-Temperature Selective Area Solid-Phase Epitaxy Using Metal Eutectics. $18,000

Rafael Alvarez-Gonzalez, Texas C of Osteopathic Medicine. Chemical and Kinetic Mechanisms of Enzyme-Catalyzed Polymerization Reactions. $21,000

Gray E. Bebout, Lehigh U. Application of Nitrogen Isotopes to Studies of Crustal Volatile Production and Transport. $21,000

David B. Berkowitz, U of Nebraska, Lincoln. Synthesis and Evaluation of a Class of Mechanism-Based Inhibitors for Phosphoryl Transfer Enzymes. $21,000

Craig R. Bina, Northwestern U. Thermodynamic Constraints upon Lithospheric Structure, Composition, and Mineralogy. $18,000

D. Scott Bohle, U of Wyoming. Lower Phosphorus Sulfides and Oxides as Reactive Intermediates. $21,000

Mary K. Boyd, Loyola U of Chicago. Photochemistry of 9-Xanthylium Ions. $21,000

Lee Brammer, U of Missouri, St. Louis. High-Resolution Diffraction Studies of Transition-Metal-Hydrogen Interactions. $21,000

Rebecca Braslau, U of California, Santa Cruz. Enantioselective Hydrogen Abstraction by Prochiral Radicals. $21,000

Kevin L. Bray, U of Wisconsin, Madison. Effect of Pressure on Optical Properties of Paramagnetic Ion Laser Materials. $18,000

Wesley R. Burghardt, Northwestern U. Polymer Crystallization in Immiscible Solutions and Blends. $21,000

James W. Canary, New York U. C_3-Symmetric Organometallic Receptors. $18,000

H. Keith Chenault, U of Delaware. Enzyme-Catalyzed Glycosylations Using Glycals and Glycosyl Phosphates as Glycosyl Donors. $21,000

Jerzy Cioslowski, Florida State U. Rigorous Interpretation of Electronic Wavefunctions: Electronic Structures of Boron Hydrides and Other Electron-Deficient Molecules. $18,000

David M. Collard, Georgia Inst. of Technology. Control of Conducting Polymer Morphology by Self-Assembly of Electroactive Monomers. $21,000

Dale G. Drueckhammer, Stanford U. Enzymatic Synthesis of Coenzyme A Analogs. $18,000

Menachem Elimelech, U of California, Los Angeles. Coupling between Hydrodynamics and Colloidal Interactions in Particle Deposition in Porous Media. $18,000

Randy S. Fishman, North Dakota State U. Void Formation in Organic Coatings. $21,000

Lorraine F. Francis, U of Minnesota. Structural Evolution of Porous Titania Coatings. $21,000

Vasilios Galiatsatos, U of Akron. Fundamental Optical Studies of Polymer Networks. $21,000

Robert T. Hembre, U of Nebraska, Lincoln. Four-Electron Redox-Coupled Reductive Elimination in Oxo-Metal Clusters. $18,000

David J. Jebaratnam, Northeastern U. A Novel Strategy for Receptor Design and Synthesis. $18,000

John F. Kauffman, U of Missouri, Columbia. Picosecond Time-Resolved Laser Studies of Solvation and Reactivity in Supercritical Fluids. $21,000

Chaitan Khosla, Stanford U. Understanding Structure-Function Relationships in Polyketide Syntheses. $21,000

C. Vijaya Kumar, U of Connecticut. Probing Hydrophobic Binding Sites in the Grooves of the DNA Double Helix. $18,000

Donald P. Land, U of California, Davis. Time-Dependent Analysis of Surface Molecular Composition. $18,000

Sara Majetich, Carnegie Mellon U. Measurement of Size-Dependent Cadmium Sulfide Microcrystallite Properties. $18,000

Nancy Makri, U of Illinois, Urbana-Champaign. Quantum Mechanical Approach to Molecule-Surface Reaction Dynamics. $18,000

Peter S. Mozley, New Mexico Inst. of Mining and Technology. Diagenesis of the Ivishak Formation, North Slope, Alaska: a Petrographic and Geochemical Study. $21,000

Margaret M. Murnane, Washington State U. Picosecond X-Ray Molecular Dynamics. $18,000

Steven P. Nolan, U of New Orleans. Thermochemistry of Olefin Iron Carbonyl Complexes: Thermochemistry Related to Olefin Catalysis. $21,000

James S. Nowick, U of California, Irvine. Template Catalysis of the Diels-Alder Reaction. $21,000

Francisca E. Oboh, U of Missouri, Rolla. Palynostratigraphy and Climatic History of the Lower Oligocene in the Eastern Gulf Coast. $21,000

Raymond A. Pearson, Lehigh U. Determining the Minimum Particle Size for Rubber-Toughened Epoxies. $18,000

Piotr Piotrowiak, U of New Orleans. Intramolecular Excitation Transfer Bands. $21,000

John A. Pojman, U of Southern Mississippi. Traveling Fronts of Addition Polymerizations. $21,000

Richard T. Scalettar, U of California, Davis. Quantum Simulations of Bose Systems: Applications to Superconductor-Insulator Phase Transitions. $18,000

Jurgen Schnitker, U of Michigan. Dynamical Simulation of Liquids with Semiempirical Electronic Structure Techniques. $18,000

Pamela J. Shapiro, U of Idaho. Investigation of the Synthesis and Reactivity of Bent Chromocene Complexes Having Linked Cyclopentadienyl Ligands. $21,000

Andrew K. Shiemke, West Virginia U School of Medicine. Biological Methane Oxidation: Spectroscopic Characterization of Methane Monooxygenase. $18,000

Seung K. Shin, U of California, Santa Barbara. FT-ICR Studies of Organometallic Reaction Mechanisms. $18,000

Bradley D. Smith, U of Notre Dame. The Synthesis and Study of Photoresponsive Receptors and Catalysts. $21,000

Thomas C. Squier, U of Kansas. Relationships between Acyl Chain Structure and Bilayer Stability. $21,000

Keith J. Stine, U of Missouri, St. Louis. Studies of Phase Behavior and Domain Structures in Langmuir Monolayers. $18,000

Paul J. Strykowski, U of Minnesota. The Effect of Counterflow on the Stability and Mixing of Variable Density Jets. $18,000

Gary A. Sulikowski, Texas A&M U. Development of Copper-Catalyzed Asymmetric Photochemical Processes. $21,000

Claire Welty, Drexel U. Stochastic Analysis of Dispersive Transport of Variable Density and Viscosity Fluids in Porous Media: Extension to the Anisotropic Case. $18,000

Vicki H. Wysocki, Virginia Commonwealth U. Structure and Reactivity of Novel Distonic Radical Cations and Anions. $21,000

Luping Yu, U of Chicago. New Polymeric Materials for Nonlinear Optics. $18,000

Chong Zheng, Northern Illinois U. Studies of Thermodynamic Properties of Solid-State Materials. $21,000

Samuel A. Abrash, U of Richmond. Wavelength Dependence and Polarization Studies of Hydrogen-Bonded Complexes in Inert Gas Matrices. $18,000

Christopher R. Arumainayagam, Wellesley C. Studies of Collision-Induced Surface Chemistry. $18,000

A. M. R. P. Bopegedera, Evergreen State C. Infrared Spectroscopy of Metal Monohydrides, Monodeuterides, and Monohalides. $18,000

Ronald G. Brisbois, Davidson C. Application of Aromatic Annulation Strategies to the Synthesis of [m.n]orthoparacyclophanes. $18,000

Laura F. Cooley, Rhode Island C. Excited-State Equilibrium Constants and Proton Transfer Rates in a Series of Ruthenium Complexes. $18,000

Ronald J. Duchovic, Indiana U-Purdue U, Fort Wayne. Bimolecular Kinetics and Reaction Dynamics. $18,000

Mark A. Evans, Georgia Southern U. The Migration of Fluids along Regional Decollements in a Foreland Fold-and-Thrust Belt. $18,000

Douglas H. Green, Ohio U. Compressional and Shear Wave Attenuation Mechanisms in Fluid-Saturated Silicic Clastics at Elevated Pressures. $18,000

Arthur S. Hewitt, California State U, Fullerton. Mechanistic and Kinetic Study of the OH + Toluene Reaction Using Laser Ionization Methods. $18,000

Helen O. Leung, Williams C. Pulsed Molecular-Beam Fourier-Transform Microwave Spectroscopic Study of Weakly Bound Complexes of Unsaturated Molecules. $18,000

Jennifer L. Muzyka, Roanoke C. Temperature Effects on Semiconductor Photocatalyzed Reactions. $18,000

Cynthia S. St. Clair, Cornell C. Metal Substitution Studies of the Blue Copper Protein Rusticyanin. $18,000

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type SE)

Udo H. Brinker, on behalf of SUNY, Binghamton, and the 24th Reactions Mechanisms Conference Committee. Reactions Mechanisms, 24th Reaction Mechanisms Conference, Orono, Me., June 1992. $2000

Malcolm H. Chisholm, Cynthia M. Friend, on behalf of the ACS Division of Inorganic Chemistry. The Related Chemistries of Clusters, Surfaces, and Solids, ACS national meeting, Washington, D.C., fall 1992. $2000

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C&EN

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PROPYLENE OXIDE

New technology may improve process economics Page 9

CHEMICAL & ENGINEERING NEWS

C&EN

MARCH 2, 1992

News of the Week

- Systematic studies of silicone breast implants are likely to be undertaken, following recommendation by FDA advisory panel to keep implants on market, but under strict limits and monitoring. **Page 4**
- New policy on biotechnology products calls for regulating them on same basis as conventional products—on their risk, not on how they are made. **Page 5**
- Pure Air, a joint venture formed by Air Products and Mitsubishi to sell flue gas desulfurization technology, is offering to trade pollution rights for sulfur dioxide emissions as part of its market strategy. **Page 6**
- Solving environmental problems and achieving sustainable development won't be possible without stabilizing world population, warns a joint report of the U.S. National Academy of Sciences and the Royal Society of London. **Page 6**

COVER: Arco Chemical's new propylene oxide plant at Channelview, Tex., is scheduled to start up later this year.

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ISSN 0009-2347

BUSINESS

Chemical industry hopes to salvage its plan for lowering and harmonizing tariffs in the current Uruguay round of multilateral trade negotiations. **Page 13**

GOVERNMENT

Tenth edition of "Science & Engineering Indicators" takes a more international approach in its report and analysis of statistics pertinent to these two disciplines. **Page 16**

Group of past NSF Presidential Young Investigator awardees calls for more support for college teachers in effort to improve science literacy. **Page 17**

U.S., Russia, and Germany form international science and technology center aimed at employing former Soviet weapons scientists on nonmilitary projects in effort to thwart researchers' possible collaboration with Third World nations or terrorists. **Page 18**

SCIENCE/TECHNOLOGY

The seven resource centers of Caltech's Beckman Institute allow interdisciplinary research in the fields of chemistry, biology, materials science, and polymer science. **Page 23**

Funding for a massively parallel supercomputer to advance the field of structural biology is being sought through a grand challenge grant proposal. **Page 25**

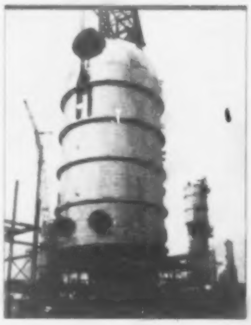
ACS NEWS

Council will consider two petitions to amend the bylaws next month in San Francisco; one on committee restructuring is likely to generate a good deal of debate. **Page 26**

FINAL PROGRAM

ACS spring meeting in San Francisco will be the largest national meeting ever, featuring over 6200 papers; exposition will comprise about 425 booths. **Page 33**

COVER STORY



Improved processes are helping propylene oxide producers keep their businesses healthy, but new plants and producers entering the market threaten to create overcapacity for the chemical. Page 9

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
Robert H. Marks, Director, Publications Division

PUBLISHING BOARD: Ned D. Heindel *(Chairman); Board of Directors Chairman:* Joseph A. Dixon; *President:* Ernest L. Eliel; Richard L. Deming; Judith C. Giordan; William P. Jencks; and Gary J. Long

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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Earlier work on bromoaromatics

In a Science/Technology Concentrates section (C&EN, Jan. 13, page 20), attention was given to our recent article in the *Journal of Organic Chemistry* on hypochlorite-induced replacement of aromatic bromine by chlorine. I have just been made aware of relevant work accomplished by O'Connor and Burrows [*J. Org. Chem.*, **56**, 1344 (1991)], which should have been cited in our paper.

The latter described efficient, nickel(II) complex catalyzed aryl-halogen exchange (including quantitative conversion of C_6H_5Br to C_6H_5Cl in 30 minutes) using NaOCl. (In contrast, only 1 to 2% production of C_6H_5Cl from C_6H_5Br was observed in the absence of Ni(II) catalyst.) The O'Connor/Burrows paper describes a breadth of synthetic utility for the Ni(II) catalyzed system and includes a noteworthy mechanistic discussion. We thank Burrows for bringing her work to our attention.

R. G. Landolt
Texas Wesleyan University, Fort Worth

Supercritical water oxidation

We were pleased to see the attention given to supercritical water oxidation in the special report by Robert W. Shaw et al. (C&EN, Dec. 23, 1991, page 26). However, we do not feel that the report fully reflects the progress that has been made in this field in the private sector.

ABB Lummus Crest Inc. became the worldwide, exclusive licensor of the Modar supercritical water oxidation technology in 1989. We have now completed two years of intensive engineering development on the process in collaboration with Modar Inc. Specific areas that required focused engineering development included process design and scaleup of the oxidation reactor, control of (sticky) precipitating salts, corrosion and materials of construction for the reactor and downstream equipment, mechanical design of the reactor and other high-pressure equipment, and integration of the process into a safe, environmentally acceptable system. It was necessary in this development to evaluate limitations and constraints imposed by materials and mechanical design, as well as to consider normal process concerns.

The above efforts have progressed far enough to proceed with the next step of designing and constructing a supercritical water oxidation demonstration plant. ABB Lummus Crest is actively pursuing opportunities for such a facility.

Herbert E. Barner
Technology Development Manager
ABB Lummus Crest Inc.
Bloomfield, N.J.

I have read with interest the special report on supercritical water. There are several statements that require clarification to describe more correctly the status of development of supercritical water oxidation technology.

Our company, Modar Inc., has been developing supercritical water oxidation processes for the destruction of hazardous aqueous wastes containing organics since the early 1980s. The original process patents, as well as several other subsequent patents from employee inventors, are all property of Modar Inc.

In the middle to late 1980s, Modar conducted two pilot-scale field tests, successfully processing hundreds of gallons per day of wastes containing polychlorinated biphenyls, priority pollutants, and the effluents from a pharmaceutical manufacturer. Beginning in October 1991, the U.S. Department of Energy, Stone & Webster Engineering Corp., and Modar have been undertakening an 18-month pilot-scale program aimed at treating 500 gal per day of wastes containing halogenated organics and substantial quantities of inorganic salts.

In 1989, ABB Lummus Crest of Bloomfield, N.J., became the worldwide, exclusive licensor of the Modar technology. After two years of engineering development, the process is ready for large-scale demonstration.

William R. Killilea
Vice President
Modar Inc., Natick, Mass.

Nutrient-based treatments

Burton Kallman's letter (C&EN, Dec. 2, 1991, page 4) is important in drawing attention to the neglect of nutrient-based procedures for treatment and prevention of diabetes, relative to the use of drugs. Trouble is, the drug industry is really only interested in chemotherapeutic agents for which they can get strong patents, and that tends to exclude nutri-

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Propylene Oxide Producers Look for Ways To Counter Sluggish Market

■ *Process improvements may lower production costs, but overcapacity threatens as new plants, producers enter business*

Susan J. Ainsworth, C&EN Houston

The U.S. propylene oxide market is experiencing some serious growing pains, and producers are actively taking precautions to ensure that their businesses remain healthy. The industry is seeing new technologies that may lower the cost of production, but at the same time, new producers and plants are contributing to the possibility of capacity vastly outstripping demand during the mid- to late-1990s.

Arco Chemical, with the newest plant, is probably studying these changes as intensely as anyone in the chemical industry. Sometime in the third quarter of this year, the company plans to start up a world-scale plant to produce both propylene oxide and styrene via the ethylbenzene peroxidation process at its Channelview, Tex., complex. The plant will have capacity to produce 500 million lb of propylene oxide and 1.13 billion lb of styrene annually.

For many years Arco Chemical and Dow Chemical have shared the propylene oxide market in the U.S. exclusively, each claiming about half of the business. The chemical is used primarily to make urethane polyols and propylene glycol. But last June, Texaco Chemical announced its intent to enter the market as a third producer, with a new plant to produce propylene oxide and methyl *tert*-butyl ether (MTBE) coproducts using the isobutane peroxidation process to go on stream in early 1994.

In addition, Dow Chemical is considering using lime instead of caustic soda in its chlorohydrin process for making propylene oxide. This likely would improve its cost position and free up a significant amount of its caustic for merchant sales. Another factor making the U.S. propylene oxide market less friendly is the recession, which has deflated demand for propylene oxide and some of its coproducts, such as styrene, and for end-use products such as flexible and rigid foams for furniture and auto seats.

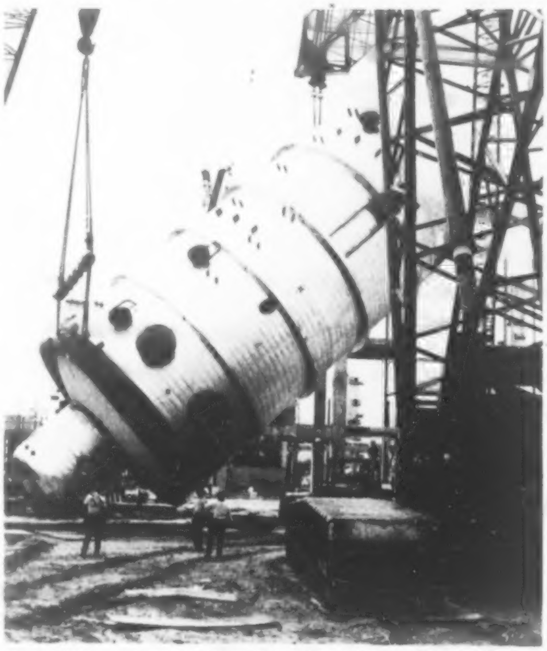
Although unfavorable market conditions and increased competition may have a negative effect on all U.S. propylene oxide producers, Arco Chemical and some industry observers believe that the company is best positioned to meet these challenges. That's because the company has the best cost position, a wealth of experience in operating propylene oxide plants, and equity partners to ease the burden of its coproduct styrene business.

It is tough for anyone to predict when propylene oxide demand will rebound. The market for propylene oxide is closely tied to the gross national product because it goes toward the production of "big-ticket consumer items such as automobiles and home furnishings," says Ronald L. Gist, a senior consultant at Pace Consultants in Houston.

Growth in propylene oxide may be buoyed by growth in demand for two key end uses—urethane polyols, which are used to make both flexible and rigid urethane foams used in automobiles, furniture, and bedding products; and propylene glycol, used in the production of unsaturated polyester resins for reinforced plastics, humectants for tobacco and food products, and for solvents used in the cosmetics industry.

"When the economy grows fairly robustly, propylene oxide grows a little faster than the economy," Gist says. On the other hand, "when there is a downturn, big-ticket items drop lower on a consumer's priority list, and propylene oxide grows slower than the GNP," he adds. Gist estimates that propylene oxide demand in the U.S. dropped less than 1% in 1991, but that it will grow about 1.5% between 1991 and 1992 and 2.6% per year in the mid-1990s.

Arco Chemical's forecast is brighter. From now through the mid-1990s, the company expects use of propylene oxide to grow 4% per year and that of styrene 3% per year in the U.S. Worldwide, the company predicts that propylene oxide



Crane lifts concentrator drum into place at Arco Chemical's Channelview, Tex., propylene oxide unit will grow 6% per year and styrene 4% per year through the middle of this decade.

Still, increases in consumption of propylene oxide probably won't compensate for the planned jump in production. Propylene oxide operating rates in the U.S. are now holding at about 85%, but that will likely drop to roughly 65 to 70% in 1994 when Texaco's capacity comes on stream, says Michael Horvath Jr., a petrochemical consultant with Petrocon Associates in Houston. "There is absolutely not enough room for another plant in this market right now."

Indeed, the market has changed significantly since Arco Chemical broke ground for its plant in June 1990. "The lead time it takes to start up a plant of this size is tremendous," says Joseph T. Lee, manager for projects and development at Arco Chemical. "Our first authorization for spending was back in 1988 when the market was robust, demand was strong, and everybody in the industry was operating near capacity."

When Arco Chemical decided to build the new plant, it considered two in-house peroxidation routes to propylene oxide. One starts with isobutane and gives a *tert*-butyl alcohol (TBA) coproduct, which can be converted to the gasoline additive MTBE. The other route, which the company eventually decided on, starts with ethylbenzene and produces coproducts propylene oxide and α-methylbenzyl alcohol, which can be dehydrated to styrene. Arco Chemical says it was not easy to decide between the two processes. Unfortunately, it is not technically feasible to operate a propylene oxide plant on a swing basis such that either of the two coproducts can be produced to satisfy demand fluctuations. "We thought both were relatively good investments," recalls Lee.

Arco Chemical chose the propylene oxide/styrene process because it would give it a better coproduct balance for styrene and MTBE in its worldwide market, says Lee. All of its European propylene oxide operations and two thirds of its U.S. propylene oxide operations are MTBE-based. The company did not want to be "weighted on that one technology" too heavily, he adds. On the other hand, "we think that styrene is a viable long-term business, and we are well positioned to operate within it."

Since those big decisions were made, "we've had to try to forecast where the industry and the overall economy were going to go." Arco Chemical, Lee adds, "anticipated a recovery some time in 1991 and it did not materialize."

Nevertheless, the company maintains that its investment in the new plant was necessary to position itself to meet its customers' needs into the future. "There's always going to be swings up and down [in demand], but we have a responsibility to our customers to guarantee that we can get materials to them," Lee says.

Horvath says that although lower operating rates will hurt all three propylene oxide producers, Arco Chemical will likely weather the storm best. Lee says, "We think the new Channelview unit will have the best [ratio of] capital per pound of product produced for this technology. It will probably be the most energy efficient plant of any of the propylene oxide–styrene units we have built. And because this is our newest plant, it is, environmentally, the tightest plant we have built."

Experience in building and operating propylene oxide plants is one factor that Arco Chemical has on its side. The company has been producing propylene oxide via the peroxidation process since the late 1960s, when it built its first such plant at Bayport, Tex. It has since fine-tuned its technology while building each of its nine propylene oxide plants around the world.

"There have been a lot of changes in just physical equipment alone," says Donald P. Mykytiuk, director of project management at Arco Chemical. Process improvements have evolved over time and with each new plant, and the older plants have been retrofitted to continually bring them up to date.

The construction strategy for the new plant involved off-site fabrication whenever possible to cut costs, says construction manager John T. Casey. For instance, Arco Chemical had two oxidizers fabricated and brought from Japan to the plant site, notes Mykytiuk. It also modularized the pipe racks for the plant and brought the units in by truck and barge.

With the expertise and technology improvements that Arco Chemical has honed over the years, "we now can get superior yields and efficient production out of smaller pieces of equipment," says Terry L. Stierman, technical superintendent at the new plant. "We've learned how to spend less capital but still get the best cost efficiency, energy efficiency, and yield efficiencies compared with any of Arco Chemical's previously built plants, all while maintaining high quality," he says.

Texaco also may have an edge in the marketplace by virtue of its peroxidation technology. When the company's propylene oxide and TBA facility in Port Neches, Tex., starts up in early 1994, it will enable Texaco to produce 400 million lb per year of propylene oxide and increase MTBE production from its current 4500 barrels per day to 19,500 bbl per day at Port Neches.

Now that Arco Chemical's basic patents on its peroxidation process have expired, some question whether Texaco's process is borrowed. A Texaco spokesman confirms that the company is employing a peroxidation process that yields propylene oxide and TBA coproducts, a process that in basic terms has long been used by Arco Chemical and other companies outside the U.S. But he adds that the process is "not identical to anyone else's process. It is our own proprietary process." Ralph S. Cunningham, Texaco Chemical president, says, "This project has additional importance because it uses technology that originated at Texaco Chemical's Austin [Texas] Research Laboratory. It is an example of developing proprietary technology to expand the company's product line."

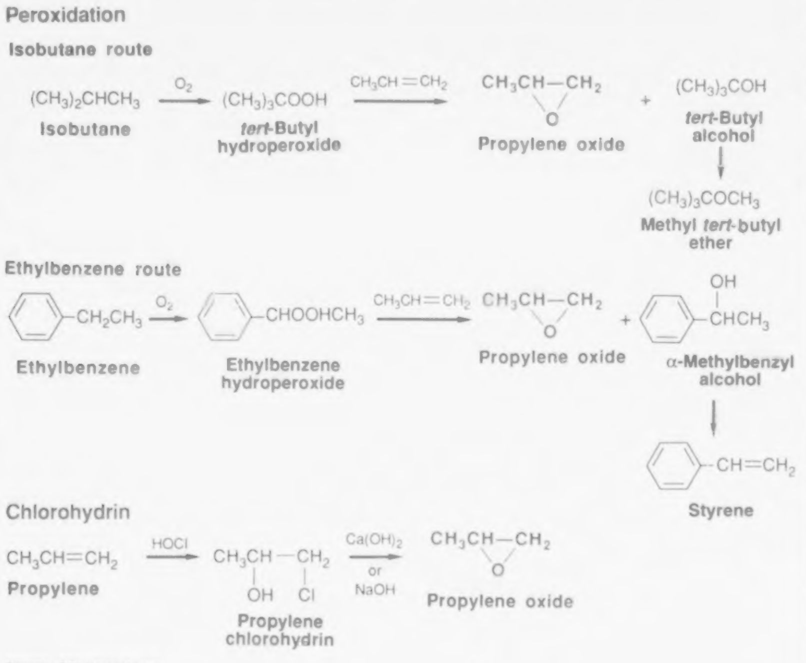
The expiration of basic patents on

Three firms will share U.S. market for propylene oxide

	Location	Annual capacity (millions of lb)	Basic process
Arco Chemical	Bayport, Tex.	1213	Peroxidation (isobutane)
	Channelview, Tex.	1100[a]	Peroxidation (ethylbenzene)
Dow Chemical	Freeport, Tex.	1100	Chlorohydrin
	Plaquemine, La.	450	Chlorohydrin
Texaco Chemical	Port Neches, Tex.	400[b]	Peroxidation (isobutane)

a Of this capacity, 500 million lb is slated to come on stream with a new unit in third-quarter 1992. **b** Slated to start up in first quarter 1994.

Two major processes are used to produce propylene oxide


Peroxidation
Isobutane route
$(CH_3)_2CHCH_3$
Isobutane
O_2
$(CH_3)_3COOH$
tert-Butyl hydroperoxide
$CH_3CH{=}CH_2$
$CH_3CH{-}CH_2$
O
Propylene oxide
+
$(CH_3)_3COH$
tert-Butyl alcohol
$(CH_3)_3COCH_3$
Methyl tert-butyl ether
Ethylbenzene route
$-CH_2CH_3$
Ethylbenzene
O_2
$-CHOOHCH_3$
Ethylbenzene hydroperoxide
$CH_3CH{=}CH_2$
$CH_3CH{-}CH_2$
O
Propylene oxide
+
OH
$-CHCH_3$
α-Methylbenzyl alcohol
$-CH{=}CH_2$
Styrene
Chlorohydrin
$CH_3CH{=}CH_2$
Propylene
HOCl
$CH_3CH{-}CH_2$
OH
Cl
Propylene chlorohydrin
$Ca(OH)_2$
or
NaOH
$CH_3CH{-}CH_2$
O
Propylene oxide

Source: SRI International

Arco Chemical's peroxidation process does not necessarily open the market up to all comers. Arco Chemical does not doubt that Texaco has done its own development work. The know-how necessary to operate a propylene oxide plant "goes way beyond what we put in a patent," says Lee. Taking technology from bench scale to commercial scale is complex, he adds, "and there are many safety and operating issues that you don't learn overnight. Anyone in an oxidation business can tell you that mixing hydrocarbons and oxygen is not without some inherent risk. With a number of years of operating experience, we have become more knowledgeable about how to operate. Besides, it is not a cheap technology to get into. I think that's one of the reasons we have held the position we have for a number of years."

Dow is likely to be hardest hit by the flood of new propylene oxide capacity, mainly because the processes used by Arco Chemical and the new Texaco plant provide significant cost advantages when the primary products, styrene and TBA, enjoy strong demand and pricing, says Petrocon's Horvath. "One major factor that may have influenced Texaco's decision to use the TBA process is the magnitude of the gasoline market, which will easily consume all of its TBA in making MTBE. So, propylene oxide may or may not be the driving force behind the new plants." By taking a cautious approach and not opting to add another propylene oxide plant, Dow will be in an awkward position in the near future, he says. "There's no room for another propylene oxide plant and there won't be for a long time unless Dow develops some breakthrough technology or replaces current chlorohydrin technology with a competitive peroxidation process."

Dow disagrees. David Naessens, product manager for polyurethane chemicals at Dow Plastics in Midland, Mich., says: "We don't see ourselves being at a great disadvantage. We obviously have done a lot of work looking at both of Arco Chemical's processes, and our conclusion is that after all of the depreciation of our plants, we are indeed competitive." In addition, he says, "unlike Arco Chemical and Texaco, we are not encumbered by coproducts. We run for propylene oxide economics alone."

Another plus on Dow's side is that the majority of the propylene oxide Dow makes is used internally. Texaco and Arco Chemical, he says, will have to rely more on merchant market sales. "Therefore, we will be running our plants at a higher rate of capacity." And he says Dow has not lost its chance to add capacity. Just last summer, Dow brought on a 200 million-lb-per-year expansion at Freeport and "we have another 400 million lb increment available to us there that we will bring on as the supply and demand balance dictates."

If Dow does modify its U.S. chlorohydrin process plants to use lime instead of caustic soda, the company will be more competitive with Arco Chemical on a cost basis, Horvath concedes. Lime, at roughly $50 per ton, is cost-effective compared with caustic soda, which trades at about $220 per ton. And the switch to lime would allow Dow to free up a significant amount of caustic soda to supply to merchant buyers without having to increase coproduct chlorine production.

Making the switch even more attractive, Dow is capable of producing its own lime. "Dow uses a lot of calcium carbonate and calcium chloride from sea shells in its magnesium process and it is very easy to convert calcium carbonate to calcium oxide, which is lime," Horvath adds. "In fact, Dow has drying furnaces at Freeport" that it can use to roast calcium carbonate limestone until all the carbon dioxide is driven off to make commercial calcium oxide, also known as caustic lime. "So it would be very easy for Dow to use that in a chlorohydrin process," Horvath conjectures. Naessens says that Dow has not yet decided to go with a lime process and that if it did, the company has many options for obtaining lime—and making its own is just one.

The switch is technically feasible; Dow already has propylene oxide facilities in Brazil and in Europe that use lime. What the company does have to ponder is the cost of converting its propylene oxide facilities at Freeport and Plaquemine, La., which would be considerable. The Freeport unit has pro-

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pylene oxide capacity for about 1.10 billion lb per year and the Plaquemine facility is rated at 450 million lb per year. "The earliest we would make a decision to implement the lime process would be around 1995 or 1996, and it will depend on the economics of propylene oxide, caustic, lime, and Dow Chemical as a whole," Naessens adds.

Using lime "is a very interesting way for Dow to use its basic raw material position to help its overall profitability and make it more competitive with Arco Chemical," adds Horvath.

Arco Chemical, like the other producers of propylene oxide in the U.S., wants to be well positioned to take advantage of increased demand for propylene oxide when the economy finally does recover, which Gist expects will happen in 1992. Arco Chemical anticipates the recession will end and that consumption of propylene oxide will rebound. The cyclical forces that brought demand for these products down also will turn back up for companies that provide materials to the automotive and housing industries, the company believes.

Some of the propylene oxide from the new propylene oxide–styrene unit will be channeled toward supplying the urethane polyols business that Arco Chemical bought from Union Carbide in September 1991. The company was a major supplier to Carbide before the purchase. In addition, Arco Chemical says, it may tap the new plant to supply the 225 million-lb-per-year polyols plant at Channelview.

A part of the new capacity also may be used to supply growing outlets for propylene glycol. For example, some uses for ethylene glycol antifreeze have been converted to products based on propylene glycol, which has a lower toxicity profile. Ingestion of ethylene-glycol-based antifreeze is a commonly reported cause of poisoning in children and pets. Arco Chemical has very active programs both in the U.S. and in Europe to market propylene glycol to antifreeze formulators. In addition, it is touting propylene glycol's safety and environmental advantages over ethylene glycol in the deicers market. Aircraft deicing fluids have been based principally on this glycol, but now it has been listed as a hazardous air pollutant and the Clean Air Act has put pressure on airlines to find a substitute, says Lee. Arco Chemical has a propylene-glycol-based product for this end use, too. "We expect that both the aircraft deicing and antifreeze markets will give us significant new business and contribute to propylene oxide demand."

Arco Chemical is also involved in developing a number of other end uses for propylene oxide, including new derivative markets, says a spokesman. One example: the company's recent entry into the butanediol market. "We think that we are positioned to do that. We have the propylene oxide supply, we have the derivative capacity."

As for the coproduct styrene, "there will be factors that will affect how much styrene we produce." Principally, it will depend on demand for both propylene oxide and styrene. Arco Chemical can afford to be less concerned about that business. It has reduced its exposure to cyclicality in the styrene merchant market by signing on "equity partners" that have committed to a "significant portion of the styrene capacity of the new plant," says a spokesman. These unnamed partners will provide raw materials and pay their share of the plant operating costs, while not directly participating in the operation of the plant.

Arco Chemical believes, too, that the billion pounds of capacity for styrene that it is adding is only a small part of the world market for styrene, which totals 35 billion lb. "So in time [that capacity] will be absorbed by the demand in the marketplace," says Lee.

The export market is another viable outlet for Arco Chemical's propylene oxide and styrene. The company's worldwide production system allows it to take material from one location to another to meet demand until a new plant is built in that region. Given the cost involved in building one of these units, says Lee, "we don't want to make this investment all that often. So the flow of materials worldwide is something that we continually optimize."

Arco Chemical seems confident that its new plant, with its safety, environmental, and operating improvements, will be well equipped to meet the many market challenges it will face when it goes on stream later this year. Says Lee: "We have engineered and improved things incrementally over the past 25 years to the point where we have the most efficient system. There's no home run breakthrough in technology here, but I guess we've won the game by way of singles year after year [that were] accomplished by constantly improving our process." ☐

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Region V election

A question concerning the recent Region V board member election that was raised in a letter from E. Ann Nalley (C&EN, Jan. 20, page 2) needs clarification. Her statement is, "Also, even though our society has strict regulations about the use of society publications in campaigning, these are often difficult to enforce." We assume that this statement was made because of an announcement of the two nominees (namely, the cosigners of this letter) in a divisional newsletter prior to public knowledge that Nalley was a third candidate by petition. This omission was corrected, as far as possible, prior to the election by a separate mailing of statements by all three candidates—at the division's expense—to the divisional membership.

Two erroneous inferences could be drawn from the Jan. 20 letter. We want to make it clear that our society's major news publication, C&EN, was not involved. It could also have been inferred from the letter that one of us was somehow responsible. That is not the case. The short newsletter announcement was, in fact, written by a new assistant editor in the absence of the regular editor.

Both of us are grateful to our supporters, and we look forward to your further participation in furthering the society's goals through our respective ACS roles.

Clara D. Craver
ACS Councilor
John G. Verkade
Director, ACS Region V

Women in chemistry

The American Chemical Society at all levels is airing its strong commitment to increase the number and participation of women in chemistry. One cannot help but wonder about the sincerity of this commitment when one sees the major chemical conferences with zero invited female speakers. One example is the last (32nd) National Organic Symposium, June 16–20, 1991, at the University of Minnesota. There were 11 speakers, all male, and five presiding officers, all male.

Today I received the program for the 23rd National Medicinal Chemistry Symposium, which lists 22 invited speakers, again all male, zero female. I have decided to boycott it on this ground. I shall not expose myself anymore to the bigotry of the major speakers paying lip service to the oftentimes numerous female chemists on the acknowledgment slides of their talks, while using their own prestigious old-boy network to exclude these or other females from the scientific visibility of the major conferences.

Vera M. Kolb
Professor of Chemistry
University of Wisconsin, Parkside

Supercritical water

Although I found the article on supercritical water (C&EN, Dec. 23, 1991, page 26) an excellent discussion of theoretical investigations into supercritical water, I believe that the following clarifications are necessary to give your readers a complete picture of the status of this technology and its practical applications.

Stone & Webster Engineering Corp. has been involved in a cooperative agreement with the Department of Energy's Office of Industrial Energy Efficiency since 1988 to demonstrate a water oxidation process in an industrial application. Since 1989, the program has focused exclusively on demonstrating the supercritical water oxidation process developed by Modar Inc. of Natick, Mass. The Modar technology was selected for demonstration by a panel of industry representatives as being the most developed wet oxidation technology available that could achieve complete destruction of an organic waste.

During the course of our investigations, we discovered that the primary obstacle to commercial application of supercritical water oxidation was not a lack of fundamental data on the supercritical fluid or oxidation reaction kinetics. Volumes of this data have been obtained empirically, but are held as trade secrets by technology developers. Our work has shown that the primary obstacle is the observed plugging of the reactor system due to the generation of reaction products—primarily sodium salts that are insoluble in the supercritical fluid. These salts are encountered when treating most waste feeds containing chlorides, sulfates, and other constituents that form acids upon oxidation. So severe is this plugging problem, that reactor systems have plugged after only minutes of operation. It is interesting to note that nearly all hazardous-waste feeds will form sticky solids during treatment. To date, this phenomenon is not fully understood, nor has

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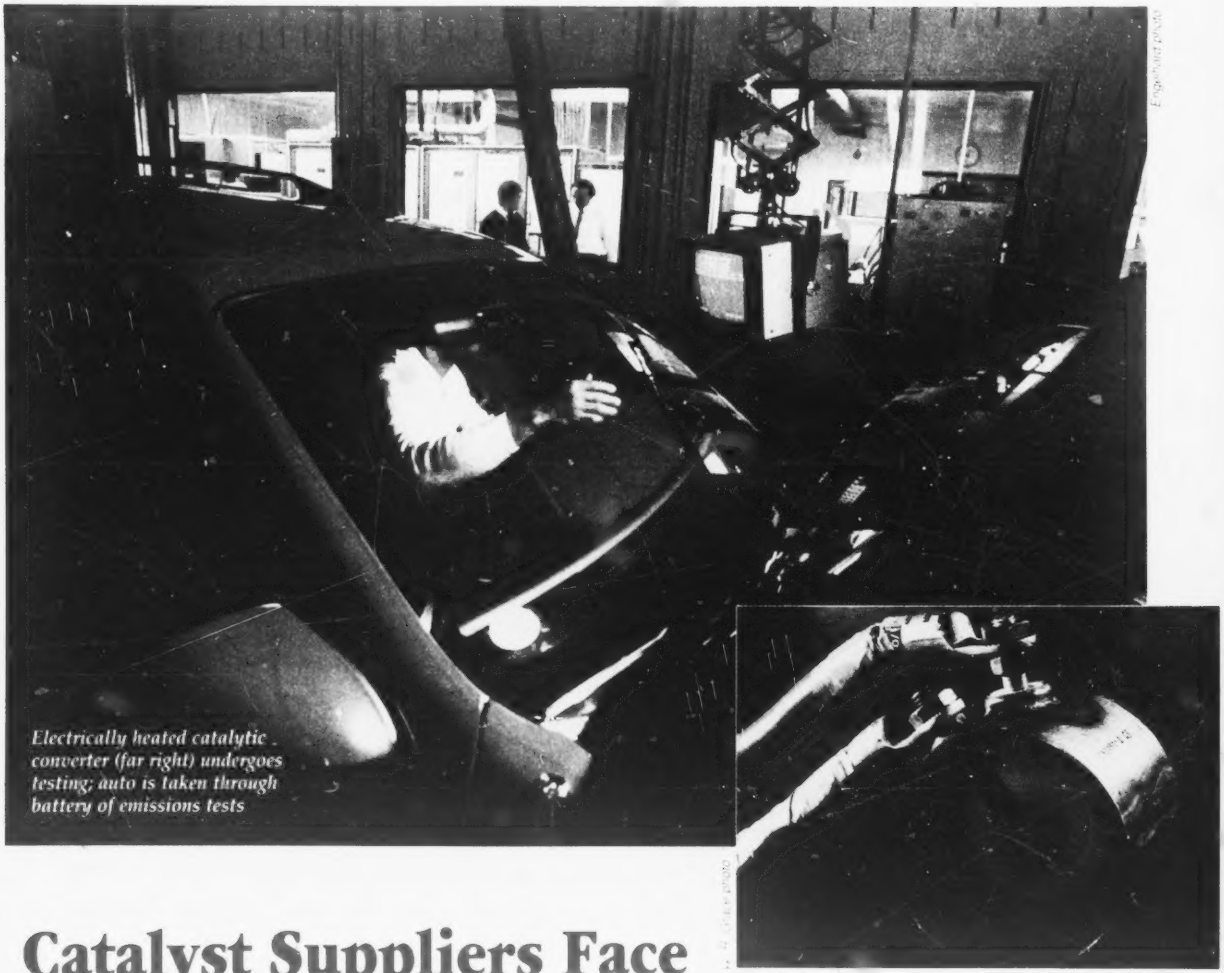

Electrically heated catalytic converter (far right) undergoes testing; auto is taken through battery of emissions tests

Engelhard photo

W. R. Grace photo

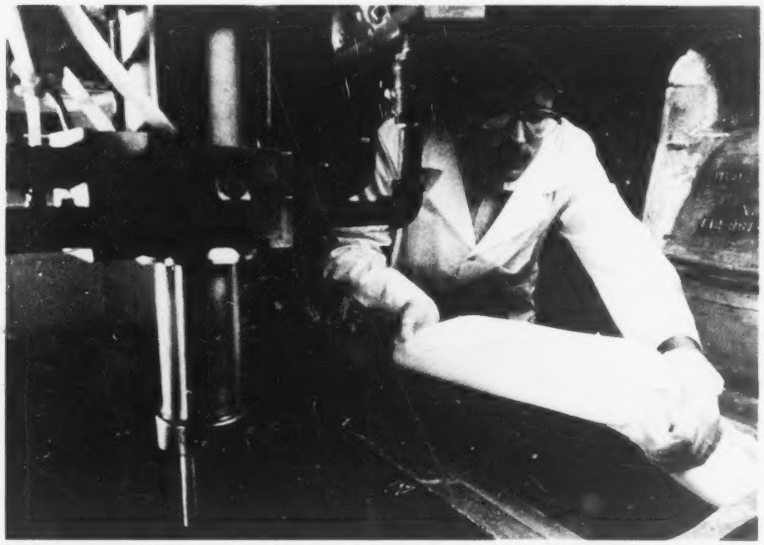
Catalyst Suppliers Face Changing Industry

Ann M. Thayer,
C&EN Northeast News Bureau

Catalyst suppliers and their customers are being pulled in many directions by recession and environmental forces. The three major catalyst markets—petroleum refining, chemical processing, and emissions control—are all facing economic, competitive, and regulatory pressures that have direct or indirect effects on markets. As a result, catalyst producers are being pushed to develop products with improved performance to meet changing environmental standards.

What has added to the complexity, challenge, and therefore opportunity in the industry is that environmental directions are putting a particular new light on how to look at process development and catalyst research, says Ricardo Levy, president of Catalytica in Mountain View, Calif., a catalyst-driven technology development firm. "The economic and environmental considerations play a very important role in defining the development of new technology. And new technology in the next decade will not succeed unless it takes that very much into account."

A catalyst supplier's success is rooted in its ability to respond to a variety of customer demands with the needed technological advances. Refiners are asking for cost-effective catalysts to meet the production requirements of reformulated gasoline, and the automotive, process, and energy industries are looking for ways to reduce emissions. Catalysts also play a key role in chemical processes by controlling the rate and direction of reactions. Here catalyst suppliers are being asked to provide cleaner, safer, and lower cost catalyst-driven routes to desired prod-



Technician researches use of catalyst in the production of polyurethane foam at Air Products laboratory

ucts, while maintaining production efficiencies.

Catalyst markets depend significantly on the prosperity of end-use markets for the products they make. The nearly $6 billion worldwide merchant catalyst market supports chemical processing and manufacturing industries that produce goods worth more than a hundred times that amount.

The worldwide market for catalysts is expected to grow about 4% per year during the next few years, according to Catalyst Group, a Spring House, Pa.-based commercial and technical consulting firm. An expanding aspect of the catalyst industry will be in the regeneration and recycling of used catalysts, explains Clyde Payn, president of Catalyst Group.

Most growth will be in Europe, in emissions catalysts, and the Pacific Rim, in catalysts for petroleum refining. Among the largest markets, the $1.6 billion European market for catalysts is projected to grow about 10% annually to $2.6 billion by 1995. Over 35% of catalysts sold worldwide, or $2.1 billion in 1990, were used in North America, based on figures from Catalyst Group. This market is expected to grow only about 4% to $2.5 billion by 1995. The North American catalyst market can be divided roughly into three segments of about equal size: petroleum refining, 35%; chemical processing, 31%; and environmental applications, 34%.

Changes in petroleum refining

No market for catalysts is in as dynamic a state of flux as that for petroleum refining catalysts. Catalysts used in refining fall into several general areas: fluid cracking catalysts (FCC), hydrocracking, reforming, isomerization, hydrotreating, and alkylation catalysts.

In the U.S., changes dictated by the 1990 Clean Air Act require new gasoline formulations; new catalysts will be needed to meet those requirements. This also must be accomplished in what producers see as a relatively short amount of time. As early as 1992 in some areas and by 1995 in many others, the Clean Air Act mandates reductions in gasoline volatility, and in benzene and other aromatics, and provides for an increase in oxygen content to reduce emissions. And, in less than two years, low sulfur and aromatics standards will be in effect for diesel fuels.

To produce the components of reformulated gasolines, the economics and roles of various refinery operations will move in different directions, influencing catalyst suppliers' products both positively and negatively. Catalyst suppliers must respond quickly with new catalysts, a move that will necessitate large R&D investments. The refining catalyst industry has been plagued by problems of overcapacity and falling prices for the past several years, along with continuing worldwide recession economics and lingering effects of the Persian Gulf War.

"The Gulf War created an artificially high demand for energy ... and that means a high demand for catalysts," says William Gustafson, group vice president and general manager of petroleum catalysts for Engelhard in Edison, N.J. "And so the recession, in at least the first half of 1991, was delayed in the oil and catalyst industries because of the need to produce energy."

Although demand was high during the Gulf War, says Al Roeder, president of Criterion Catalysts, refiners were reluctant to replace catalysts. Criterion, formed in 1988, is a Houston-based joint venture between American Cyanamid and Shell. When the war ended rather abruptly, inventories of petroleum products were quite high, especially in the U.S., leading to competition and falling prices. As a result, oil companies are reporting tremendous losses, are operating at lower capacities, and are reluctant to spend the money to shut down operations to replace catalysts.

"I think to say [petroleum refining is] in a recession is very charitable," says Roeder. "And if it is hurting, then the catalyst industry hurts." Roeder does not see the situation improving much in the near future. "The effects of shutdowns and recession are much stronger than any growth from environmental requirements. The environmental impact is uncertain and the timing is clearly unknown."

FCCs, proprietary zeolite-based catalysts of a wide array of compositions, are the highest value refining catalyst market, and Davison Chemical, a division of W. R. Grace's specialty chemical business, is the leading producer, with a worldwide market share near 40%. Other major producers are Akzo; Engelhard; and Katalistiks, the FCC business of UOP, a 50-50 joint venture between Allied-Signal and Union Carbide formed in 1988.

Used to convert petroleum into oils, gasoline and other fuels, and lighter hydrocarbon fractions, cracking catalysts are needed to produce the desired distribution of certain products. This is because gasoline, once required to meet only a few specifications, now must meet several strict composition standards. Whereas FCC units traditionally produced about 30 to 35% of the gasoline pool, these units are being viewed now as a source of feedstocks for other processes. This means reduced levels of aromatics and light alkanes and increased yields of C_4 and C_5 olefins for use as less expensive feedstocks for the production of octane-building alkylates and oxygenates.

With the ban on lead additives in gasoline, aromatics became a major source of octane in gasoline. Restrictions now on aromatics are causing refiners to look for other sources of octane. What is desired are higher fractions of isobutylene for methyl *tert*-butyl ether (MTBE) or isoamylene for *tert*-amyl methyl ether (TAME) production, which in addition to their environmental benefits, increase octane levels. The demand for MTBE in reformulated fuels is expected to more than double over the next five years. Despite planned increases in MTBE production capacity, U.S. supplies are expected to lag demand by as much as 20%.

Richard Nozemack, vice president for FCC marketing at Davison Chemical, Baltimore, sees 1 to 3% market growth in refining catalysts in the U.S. in the next few years. Such a growth would depend on several factors, he says, including a turnaround in the recession. Eastern Europe and the former Soviet republics are looked upon by catalyst producers as potentially interesting, although currently uncertain markets. Engelhard has recently opened an office in Moscow.

In the Pacific Rim, where new refinery plant construction is planned or under way, growth in refining catalysts may reach as much 5 to 6% during the next five years. Growth in Europe is anticipated to be slightly faster than in the U.S., but not so fast as in the Pacific Rim, since reformulated gasoline is not yet an issue. However, "technology growth" overall will be dramatic, Nozemack says, because of a stiff need for technological improvements over the next five years. The challenge to suppliers is to provide solutions through "catalysis rather than capital," which means new catalyst technology that can be rapidly incorporated into existing equipment.

"There is a good opportunity to serve our customers by coming up with catalytic solutions that can use the existing capital or hardware in refineries," says Gustafson. "That's a much better solution than to spend lots of money. It takes a long lead time to [build] and right now

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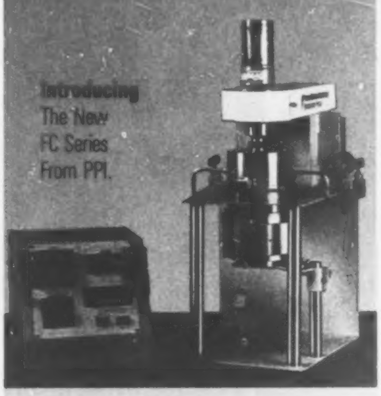

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I don't know how much lead time the industry will have if the regulations were to change." Catalyst suppliers are finding it necessary to work closely with refiners to produce catalyst formulations that perform optimally with different petroleum feedstocks and equipment, and that meet the desired product requirements.

Until about a year ago, FCC producers had been in a price war, explains Gustafson. It had been more than eight years since producers saw a price increase despite the fact that raw material, labor, and R&D costs were all increasing. Such costs, and tremendous overcapacity, have contributed to a history of rationalization and consolidation in the industry. Filtrol was absorbed by Akzo in 1989; ICI repositioned its catalysts business and sold its refinery catalyst business to Crosfield Chemicals, part of Unilever's Specialty Chemicals group, in 1990; and rumors persist about other companies reconsidering their positions, particularly in the FCC business. In 1991, Union Carbide and Allied-Signal each took a $60 million charge against earnings related to the UOP Katalistiks business.

About 18 months ago, Engelhard increased prices, Gustafson says, and in doing so lost a few percentage points in market share. However, the company believes it is in better shape as a result and sees itself as the number two supplier worldwide behind Davison Chemical, with Akzo as a close third. "Prices stabilized and have turned around, but they are not back to where they were even several years ago," he adds. "There is a continuing need to increase the price of catalysts so that the supplier has the money to invest in research and the tools in place to ensure that when industry needs it, we have the right products designed."

"We will see improvement in pricing, but it won't come fast enough to save all the companies out there," he continues. "The industry will continue to rationalize until it gets down to an acceptable number of profitable suppliers." FCC catalysts have relatively short product lives, and technological developments are crucial to staying competitive. Their value to refiners comes through increased activity, which leads to decreased catalyst consumption, and most efficient conversion of petroleum feeds. However, it is unlikely refiners will recover the investments made to meet regulations.

Value of world markets for catalysts to grow

$ Millions	1990	1995	Annual growth
North America	$2110	$2500	3.5%
Europe	1578	2571	10.3
Japan	837	1042	4.5
Other	1459	1775	4.0
TOTAL	$5984	$7888	5.7%

Source: Catalyst Consultants

Like other suppliers, Engelhard has been introducing new FCC product lines to address refiners' concerns. Its Precision line, based on new zeolite technology, and Dimension line, based on new matrix technology, make up nearly 50% of Engelhard's sales over the past two to three years. Dimension is designed to deal with heavier fuel oils to give good selectivity against coke and gas production, whereas Precision is said to optimize gasoline yield and octane. Both also are said to maximize yields of light olefins such as isobutylene and isoamylene used to produce oxygenates. Gustafson adds that Engelhard is designing its next generation of catalysts to increase isobutylene yields as much as 100%.

To meet the demands for new catalysts, Davison started up its new 90 million-lb-per-year FCC catalyst plant in Lake Charles, La., in August 1991. It produces the company's new XP series, which has been under development for 10 years. XP catalysts are said to offer superior cracking of heavier, high-boiling petroleum fractions, or bottoms, with increases both in gasoline yield and octane. The company increased its catalyst capacity at the Lake Charles facility by 50%, after closing FCC production at its Cincinnati plant and consolidating these operations to Louisiana.

Davison has a new catalyst system, not based on the traditional faujasite zeolites used in FCCs, but rather on a proprietary zeolite, the structure of which the company will not disclose, that addresses many needs of reformulated gasoline. Similarly, Akzo manufactures lines of zeolite-based cracking catalysts for increased conversion and octane levels, low gas and coke production, and enhanced bottoms cracking. Akzo's CSC, or component selective cracking, catalysts are designed to give higher percentages of branched olefins in the C_4 to C_8 range while maintaining gasoline yields.

The restriction on aromatics is also anticipated to influence the operation of catalytic reforming units that in the past have produced about 30% of the gasoline pool. UOP is by far the largest producer of reforming catalysts, followed by Criterion. Reforming catalysts, which cyclize and dehydrogenate hydrocarbons, are generally combinations of platinum with iridium or rhenium on high-purity alumina supports.

Reformers are a major source of hydrogen in refineries. The hydrogen they produce is used in hydrotreating processes—namely, the hydrogenation of aromatics or olefins and the removal of contaminants such as sulfur, nitrogen, and metals in pretreating FCC feedstocks. Although the market for reforming catalysts may fall off in the U.S., growth may occur overseas where mandated phaseout of lead additives is leading to a need for higher octane gasoline. Although MTBE could be used, Europe has not yet put environmental standards in place for reformulated gasoline, but many anticipate that that may occur soon.

An increased hydrogen demand is being driven by U.S. mandates coming into effect in October 1993 for reduced sulfur and aromatics levels in diesel fuels. Sulfur levels will have to be reduced from an average of a few thousand parts per million to less than 500 ppm, says Roeder of Criterion. Low-sulfur regulations also are being adopted in Europe and Japan. The overall market may see a few percent growth per year, but the hydrotreating catalyst industry has been plagued by overcapacity problems. Criterion and Akzo are coleaders in the hydrotreating catalyst area, says Roeder, which contains many other smaller players.

Reducing sulfur with existing catalysts requires operating at high temperatures and pressures, but that is not entirely effective on aromatics, say those in the refining industry. Severe operating conditions decrease catalyst life while increasing the use of hydrogen and catalyst. A route to aromatics saturation might be through existing precious-metal hydrogenation catalysts found in the chemical processing industry. But refiners are reluctant to adopt technologies that are foreign to the refining industry, especially if they

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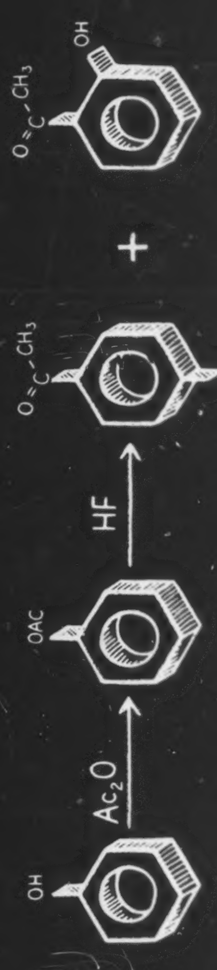

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require new construction. Thus, refiners are looking for high activity, longer-life desulfurization, and hydrogenation catalysts that work in existing units.

Hydrotreating catalysts are generally base-metal catalysts such as molybdenum with cobalt or nickel on alumina or silica. Criterion has developed a new hydrotreating process called SynSat, whereas Akzo has its Ketjenfine product line. In addition, higher quality crude oils are being depleted, says Roeder, and refiners will be faced with crudes that have higher sulfur and metal contents, leading to increased catalyst usage. Engelhard offers its HPN process to selectively hydrogenate undesirable C_3, C_4, and C_5 components such as diolefins as pretreatment for alkylation, MTBE, and TAME feedstocks.

"It's a question as to what the strategy will be for running reformers in the future," says Gustafson. "I believe that the reformer's role is going to shift from being primarily an octane supplier to primarily a hydrogen supplier." One way is to run the units at lower severity to reduce the amount of aromatics produced, but with a reduction in hydrogen needed for other processes. Engelhard, like others, is developing isomerization catalysts that may offer an alternative.

Being very similar in composition to precious-metal-based reforming catalysts, isomerization catalysts are expected to be able to be used in reforming units without major changes to the units. And isomerization gives refiners a means to deal with the low molecular weight alkanes that may be regulated under vapor pressure standards. Isomerization catalysts can convert paraffins to isoparaffins, which have increased octane values, or to materials for MTBE and alkylate production. For example, *n*-butane can be converted to isobutane which can then be dehydrogenated to produce isobutylene for MTBE. In both isomerization and FCC catalysts, there is increasing interest in shape-selective catalysts, both zeolitic and nonzeolitic materials, to control the products formed.

Through alkylation, lighter isoparaffins can be combined with small olefins to produce heavier, higher octane gasoline components. Since alkylates are desirable gasoline components, demand for alkylation catalysts is expected to increase. However, historically, this process has used large volumes of low-cost liquid acids such as hydrofluoric and sulfuric acids. Environmental and safety pressures are forcing refiners to replace corrosive, toxic, or hazardous materials with more benign or environmentally acceptable materials. In response, catalyst producers are looking for new catalytic routes to alkylation processes.

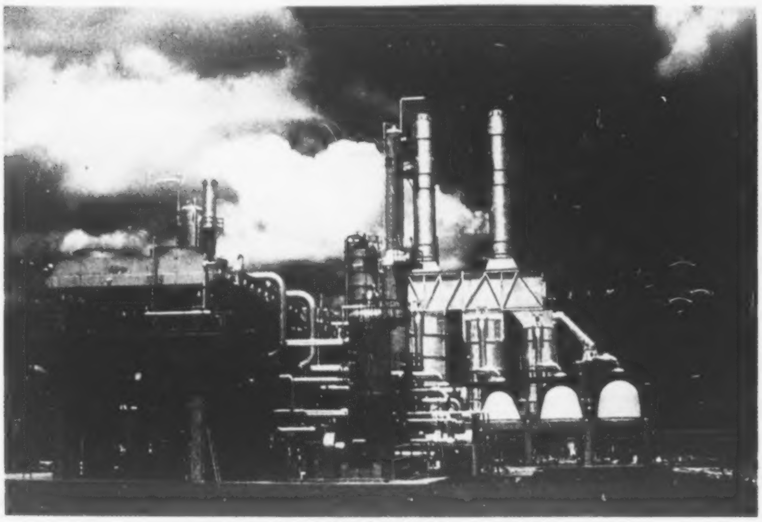
One such route targeted by many catalyst R&D efforts deals with solid acid catalysts that potentially could avoid operating costs related to handling hazardous materials. Catalytica along with Conoco, Du Pont's energy subsidiary, and Neste Oy, the Finnish oil company, have formed a joint venture to work toward commercializing Catalytica's new proprietary solid acid catalyst alkylation process. A pilot plant is planned to begin operating this fall at Neste's Porvoo research center in Finland. A key element of the process is that it allows existing liquid alkylation units to be converted to using the solid acid catalyst.

Chemical processing catalysts

Chemical catalysts play critical roles in processes in the chemical, petrochemical, petroleum, and pharmaceutical industries. The market for chemical processing catalysts is tied closely to end-use markets for the products they produce. As the chemical industry has been hit hard by the recession, so too have sales by catalyst suppliers. And competition and overcapacity in catalyst production, along with increasing raw material and R&D costs, are problems faced by the chemical processing catalyst industry.

Polymerization catalysts account for the largest dollar share of the chemical processing catalyst market at about 49%. With end-use markets for polymers down, sales in this area have been slow. Catalysts for oxidation (18%) and organic synthesis (16%) are the next largest categories, followed by synthesis gas catalysts (10%), and hydrogenation and dehydrogenation catalysts (8%). According to Catalyst Group, about 4% growth in chemical processing catalysts is anticipated overall in the U.S., although some markets will fare better than others.

According to Eugene Sanders, technical director of Calsicat, a division of Imcera's Mallinckrodt Specialty Chemicals subsidiary, Erie, Pa., the state of the economy "generally slowed down the usage of current catalysts. But it hasn't really slowed down R&D or the scaleup of catalysts for new processes. Our customers seem to be just as vigorous as ever in the pursuit of new [products]."



Gasoline reforming plant in Hawaii

Catalyst suppliers have to compete based on performance characteristics—high yields, lower operating costs, extended catalyst life, high quality, new or improved products, and attention to by-product and environmental concerns. R&D increasingly is being driven by the needs of specific customers. "More and more these days suppliers are getting away from developing one catalyst to serve a multicustomer market," says Sanders. "The competition from a performance standpoint is so keen that unless you can tailor a catalyst to fit a specific customer's needs, you are not going to be in the ball game."

Custom catalyst development is a growth area for many producers of catalysts for the chemical industry, as well as for the petroleum industry. Companies that have made their own catalysts in the past are said to be reconsidering this position during the current economic situation. This is leading to many more product development partnerships and closer, longer term relationships between customers and catalyst suppliers. It also means high R&D spending to support improvements in existing products as well as the development of new ones.

Environmental, health, and safety pressures on the use of hazardous reagents or in the production of by-products are leading to new catalytic routes to chemical products. In some cases, concerns have centered around the catalysts themselves when it comes to worker exposure or to the disposal of used catalysts. However, the desire for the most efficient catalyst may be at odds with the desire for less hazardous materials. Under these circumstances, customers often ask catalyst suppliers to take responsibility for the disposal or recycling of used catalysts.

Chemical processing catalysts are generally precious- and base-metal catalysts made on a proprietary basis. The types of catalysts and the variety of processes or products they are involved with are numerous. The result is a variety of suppliers ranging from those contributing to several markets to those with only one or two niche markets. Engelhard claims to offer the broadest range of chemical catalysts of any single manufacturer in the world. Contributing to its position was the acquisition of Harshaw, the base-metal chemical catalyst part of Filtrol-Harshaw, acquired in 1988.

The company supplies catalysts for products for a wide range of markets including automobiles, food, cosmetics, pharmaceuticals, fibers, soaps, detergents, construction, the environmental area, and packaging. "Our business is extremely leveraged in the automotive and construction industries," says William Staron, group vice president and general manager for chemical catalysts at Engelhard. "And on a global basis those industries were fairly depressed." Only Germany and the Pacific Rim have been isolated pockets of market strength, but this may not last.

"In most areas, you will find a year-over-year drop of close to 15%," he

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adds. "[What that meant was] about a 10% drop on our overall performance in 1991." Soaps and detergents and environmental applications were growth areas worldwide in 1991 for the company, but the food and beverage industry remained fairly flat. "We see very little optimism for upturn and, if it does occur, it's going to be in the second half of 1992." However, because the catalyst industry traditionally lags the economy by six to nine months, adds Staron, "we won't realize any of those benefits in 1992."

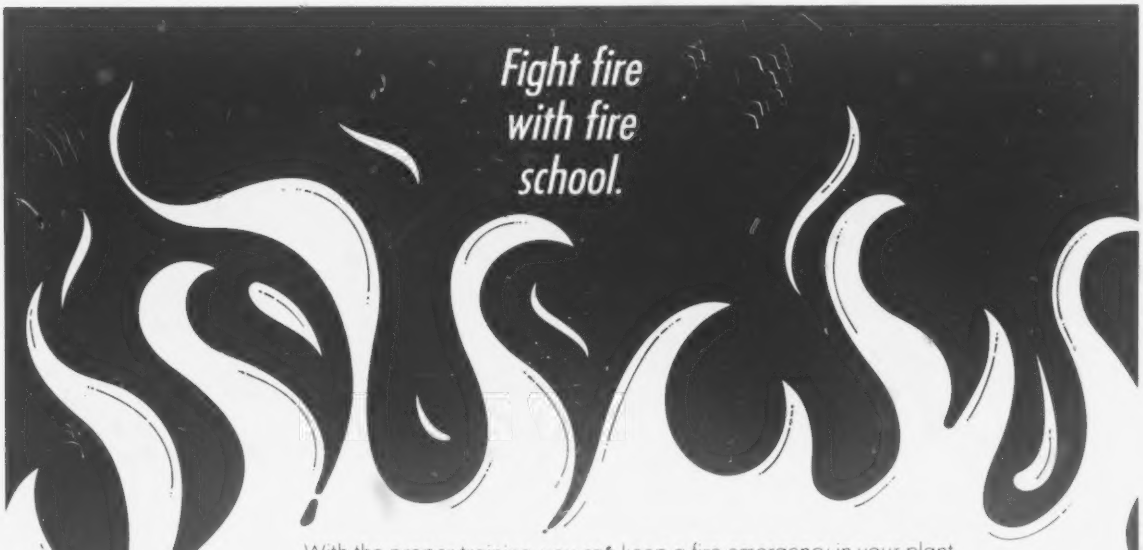
With the polyolefins industry in a period of overcapacity, which has led to declining prices and profitability, markets for catalysts are also expected to be affected. Polymerization catalysts generally are transition-metal Zeigler-type catalysts or free radical initiators such as organic peroxides. Davison Chemical produces chrome-silica, rather than traditional Zeigler, catalysts for polyethylene production. In March 1990, the company announced the construction of a new catalyst plant in Curtis Bay, Md. The plant increased Davison's production of polyethylene catalysts by 50%.

Catalyst Resources, a Houston-based subsidiary of Phillips Petroleum, manufactures polymerization catalysts and, through its Houston subsidiary Aztec Catalyst, organic peroxides. Stephen Isaacs, senior marketing development manager for Aztec, says sales were up in 1991 over 1990. "Contrasting that, there has been a surge in raw material costs, and the company has not been able to recoup all of those increased costs." Aztec and Elf Atochem are among the major producers of organic peroxides.

Catalysts for producing polyurethane foams have been hit by the recession and the resultant slow markets for autos, furniture, and construction. Other pressures on the industry have been the removal of chlorofluorocarbon blowing agents and insulating materials in the foams, explains Bruce Ernst, polyurethane additives market manager of Air Products & Chemicals. This has required firms to develop catalysts to produce the same quality foams with different reagents.

Dehydrogenation catalysts for converting ethylbenzene to styrene also have been hard hit by depressed styrene markets. With demand low, styrene producers are avoiding costs by postponing shutting down operations and changing over catalysts, explains Roeder of Criterion Catalysts, one of the leading producers of styrene catalysts. "Everything is down about the market, so [Criterion] has a plant that is reasonably unoccupied."

Another major producer, United Catalysts, a Louisville, Ky.-based company owned by Süd Chemie of Germany, views the market situation a bit differently. "Styrene prices are very low, the market is very soft, and styrene plants are operating at reduced rates and trying to cut costs," says Robert Hartye, vice president for sales and marketing at United Catalysts. "In this kind of situation, where [customers] are looking to produce the lowest cost product, they are more interested in the highest selectivity catalyst that we can supply."



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Technician performs microactivity tests at Engelhard research lab

"Fortunately for us, United Catalyst has the highest selectivity catalyst on the market, and so our market share has been very good during the past year and a half." With a big year in 1990, sales fell some in 1991, and this trend is anticipated to continue in 1992. "United Catalysts expects to have a better market share, but the total market will be reduced, and we hope there will be a rebound in 1993," Hartye says. "The company has also introduced a new styrene catalyst this year that produces less phenylacetylene, an undesired by-product." United Catalysts also supplies phosphoric acid catalysts used in the production of cumene. Because cumene goes into the production of phenol for plastics and resins, this market also was depressed this past year.

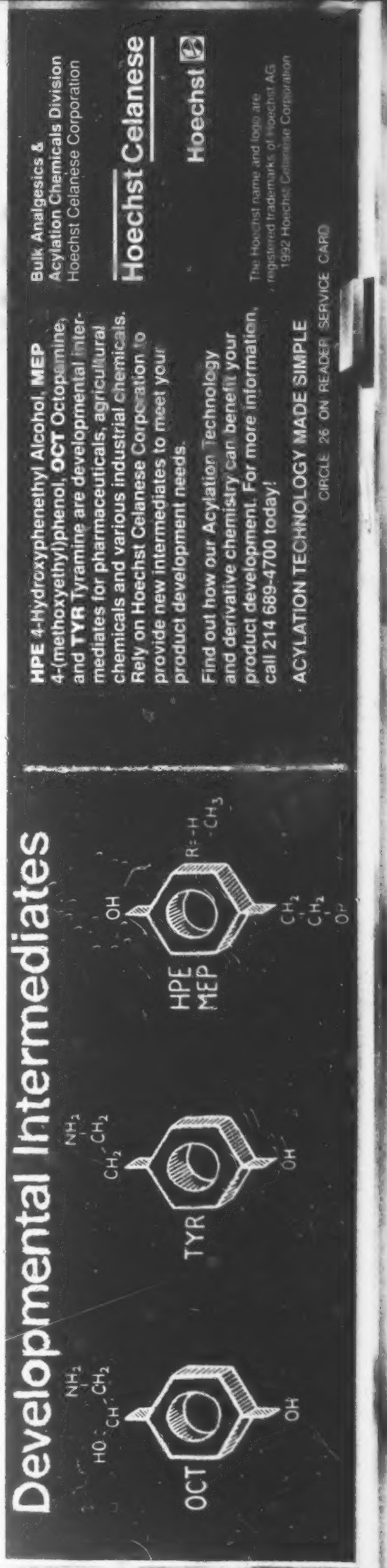
On a positive note, an exciting area in olefin polymerization is single-site metallocene catalysts, says Roger Singer, an industry consultant and head of Business Development Services in Villanova, Pa. "How these will impact older technologies remains to be seen," he says, "but for quite a while these catalysts have been the focus of many of the research departments in polyolefin producers worldwide." The area of metallocene catalysts, which consists of a broad range of catalyst compositions, is very competitive.

Metallocene catalysts are extensions of Zeigler-Natta chemistry using Group IV metals such as titanium and zirconium. However, depending on the structures and geometries of ligands on these single-site catalysts, they produce highly regular polyolefins with narrow molecular weight ranges. A better understanding and more control of the polymerization process through the design of the catalyst is expected to lead to enhanced polymers with greater uniformity in desired properties.

Dow Chemical is looking to launch its single-site constrained geometry catalyst technology in 1993. Although the technology is more than a decade old, advances made in the past five to 10 years have improved the stability, reactivity, and efficiency of these catalysts while maintaining their selectivity, says Brian Kolthammer, research associate in polyolefins at Dow. Mitsui of Japan is also actively involved in the metallocene area, as are other petrochemical and chemical companies worldwide.

Exxon Chemical's Exxpol catalyst process, its name for the single-site catalysts, is the first to be commercially offered. "I believe that metallocene single-site catalysts are going to find their way into almost every polyolefin process currently in use," says Mike Jeffries, Exxpol manager for Exxon Chemical in Houston. However, development costs have not been "insignificant," he adds.

In 1990, Exxon Chemical opened up a new 30 million-lb-per year Exxpol plant in Baton Rouge, La., to produce a range of polyolefins. Products are being aimed at specialty markets, and the company is working closely with cus-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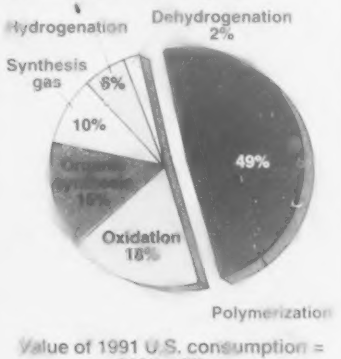
Polymers use biggest share of chemical catalysts



Value of 1991 U.S. consumption = $625 million

Source: C&EN estimates

tomers to develop polymers for their needs. "The metallocene catalysts are as competitive, and potentially more competitive, than existing catalyst systems [in terms of manufacturing costs]," says Jeffries. "Our customer response has been very strong despite the weak economic climate."

After polymerization catalysts, oxidation catalysts and catalysts for organic syntheses are the next largest markets. Many large-volume chemicals such as sulfuric acid, nitric acid, ethylene oxide, and vinyl chloride are made using metal-oxide catalysts. Monsanto is the largest producer of vanadium pentoxide for the production of sulfuric acid. Shell, among others, produces silver-oxide catalysts for the synthesis of ethylene oxide. These, like other chemical markets, have been experiencing slow growth.

Catalytica is looking at a new process for oxidizing ethylene to produce acetaldehyde that substantially reduces chlorinated hydrocarbon by-products and the costs associated with their disposal or treatment. In commercial-scale tests, the company says its process provides equivalent yields, and can be used in existing plants with little or no modification. It is also applicable to oxidation of higher olefins.

Probably the only areas with any positive outlook are the smaller markets for synthesis gas, hydrogenation, and dehydrogenation catalysts. Synthesis gas catalysts are used in the manufacture of ammonia, methanol, and hydrogen. They are typically steam-reforming catalysts consisting of iron, nickel, cobalt, or molybdenum on a supporting material generally used to convert methane in the presence of steam to carbon monoxide and hydrogen. The reaction is a source of carbon monoxide and hydrogen for the production of methanol and hydrogen used to make ammonia. Another important factor in ammonia plants are carbon monoxide shift catalysts of copper-zinc or iron-chrome used to convert between water–carbon monoxide and hydrogen–carbon dioxide.

Synthesis gas catalysts are among the largest of United Catalysts' core businesses, and the company is a leading supplier of these. Overseas companies that came into the North American market in the mid-1980s contributed to overcapacity in the industry and caused United Catalyst's market share to slip. To regain market share, United Catalysts—like other synthesis gas catalyst producers ICI, Haldor Topsøe, and BASF—has been introducing new products with higher activities and greater stability for longer catalyst life.

However, synthesis gas catalysts are a mature area technologically, having been refined by producers for decades and having little room left for further advances. "I don't know when the consumption of these catalysts will catch up to capacity. Essentially all the new catalysts we are bringing out have longer and longer lives, so that decreases the market itself," says Hartye. "Extending catalysts' lives will cut down on the total replacement business market in those areas.

"As far as the total market, 1991 was an improvement over 1990. The catalyst market looked to be up about 10 to 15% in 1991, but there still is tremendous overcapacity in catalyst production for this area worldwide." Some long-term growth is expected, however. "In North America," he adds, "I don't see any growth in ammonia plants. The growth potential is more in the hydrogen and methanol areas." Catalyst Group estimates growth of about 1% per year in catalysts for ammonia and about 5% per year in methanol.

Demand for methanol is anticipated to increase significantly because of its

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use in making MTBE for reformulated fuels. Methanol is reacted with isobutylene or isoamylene to produce MTBE or TAME, respectively. "I see some of the [methanol] plants that have been shut down, restarting here in the U.S.," says Hartye, "and so I expect catalyst sales in the methanol area to improve, both in the near term and in the long term as requirements [for oxygenates] go up."

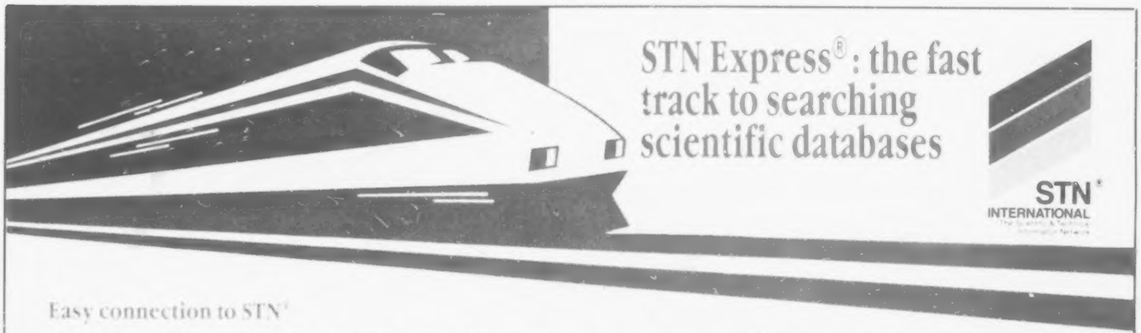
Another reason for growth in synthesis gas catalysts will come from the need for hydrogen to meet fuel desulfurization requirements. With less hydrogen being produced from reformers in refineries, an increase in construction of medium-size hydrogen plants is anticipated, leading to growth in the hydrogen area beginning almost immediately.

The market for dehydrogenation catalysts also is affected by the growth in demand for oxygenate feedstocks. Although the most inexpensive source of isobutylene or isoamylene is directly from the catalytic cracking unit, this is not expected to be enough to meet demand. Isobutylene can be produced by the dehydrogenation of isobutane to isobutylene. Thus, suppliers anticipate an increased demand for dehydrogenation catalysts. But there are no new dehydrogenation processes commercialized for isoamylene, and several companies are said to be working on this process.

Increased demand is leading to the construction of stand-alone MTBE plants in which about two thirds of the capital is in the dehydrogenation unit. United Catalysts' isobutylene dehydrogenation process is called the Houdry process, acquired, along with engineering partner Lummus Crest, from Air Products in June 1990. "At present there are only four MTBE plants based on dehydrogenation in the world, and all four of them are using the Houdry process," says Hartye. Competitors such as UOP and Phillips also offer processes and have signed up licensees.

"Because of the tremendous growth in MTBE, there has been a very large growth in our Houdry catalyst business, and already it's our second largest catalyst area," says Hartye. "And if MTBE remains the oxygenate of choice for the reformulated fuels, then we see a very, very large growth in this area for us." MTBE demand is also expected to grow in Europe, where it is currently being used as an octane enhancer, rather than for environmental concerns. United Catalysts is building a large catalyst plant in Louisville to supply the anticipated catalyst demands. Although its catalysts are chrome based, the company has worked out routes for recycling them to address disposal concerns.

Another category is hydrogenation catalysts, which may see some growth. Hydrogenation catalysts are used in petrochemical production, chemical synthesis, and fats and oils production. There are numerous competitors and, again, problems with overcapacity, particularly in the more mature fats and oils market. Engelhard is a leader in hydrogenation catalysts, says Staron, producing a wide range of base- and precious-metal catalysts used in a variety of applications. Calsicat also puts hydrogenation cata-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Refining catalysts barely lead environmental ones

North American market ($ millions)	1990	1995	Annual growth
Petroleum refining	$ 730	$ 800	1.9%
Environmental controls	720	905	4.7
Chemical processing	660	795	3.8
TOTAL	$2110	$2500	3.5%

Source: Catalyst Consultants

lysts among its primary products, and Davison sells its Raney family of hydrogenation catalysts. United Catalysts also supplies hydrogenation catalysts for fats and oils as well as for use in petrochemical processing.

Hydrogenation catalysts can be base-metal or precious-metal catalysts depending on the type of hydrogenation reaction and the desired selectivity. Platinum group metal catalysts have high activities, high selectivities, and low consumption rates under mild reaction conditions. Base-metal catalysts containing nickel, cobalt, and copper chromite are used in hydrogenation reactions, as they are in dehydrogenation, and in hydrogenolysis to produce fatty alcohols. Engelhard is working to develop chrome-free hydrogenation catalysts with the same activity and selectivity as existing catalysts.

The market for edible fats and oils will remain at about the same level this year as last year, although that for inedible fats and oils, which go into consumable goods, will decline. As in other markets, the general trend is for more active and more selective catalysts, which contributes to reduced catalyst consumption. The market also is experiencing a decline in the consumption of fully saturated fats, and so catalyst suppliers are responding with more effective catalysts for partial hydrogenation.

In petrochemicals, selective hydrogenation catalysts are used to clean up C_2, C_4, and C_5 streams going into the production of ethylene, isobutylene, isoamylene, and alkylation feeds. In heavier streams, the desire is to remove diolefins without hydrogenating the desired products. Sanders says Calsicat has had some success with a noble-metal catalyst developed to clean up C_4 streams and is working on a modification of it for C_5 streams. Similarly, in C_2 streams, the goal is to selectively hydrogenate acetylene and not ethylene. In this area, Hartye says, "United Catalysts is by far the largest supplier with about 80% of the market.

"That area has been very good over the past couple of years for two reasons," he explains. "One is new plant startups, and the other is that the company came up with a very high selectivity bimetallic catalyst." Its proprietary catalyst was introduced a couple of years ago. "It is so much of an improvement that I would say the majority of the customers in this hemisphere have either already changed out or have made plans to change out to this new generation catalyst to take advantage of its much higher selectivity."

"This has made for two very big years for us in 1990 and 1991 for these catalysts," says Hartye. However, this market is slowing down as new plant construction slows. By the end of 1992 it is expected to fall off considerably because new plants are not envisioned in the next couple of years. "As the C_2 business slows down, United Catalysts is looking to come out with improved products to pick up some market share [in selective hydrogenation catalysts for heavier hydrocarbons]," he adds.

Related to ethylene production is a new calcium, nickel, and potassium mixed-oxide catalyst, reported in late 1990, that converts methane to C_2 hydrocarbons (C&EN, Nov. 26, 1990, page 8). This past November, Lawrence Berkeley Laboratory, where the catalyst was developed, joined in a cooperative R&D agreement with Orion Advanced Chemical Technology, based in Wilmington and part of the Ferruzzi-Montedison Group. The project aims to scale up the highly selective catalyst technology to see whether it is economically feasible on a commercial level.

Growth in emissions control

The catalyst market poised for the largest growth is emissions control—both for mobile and stationary sources. Automotive catalysts long have dominated the emissions control market.

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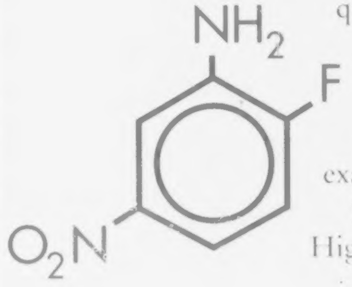

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However, increasing restrictions under the Clean Air Act are expected to open the market for pollution controls on stationary sources such as power and processing plants over the next 10 years. Catalytic technologies are aimed at controlling nitrogen oxides, sulfur dioxide, carbon monoxide, and volatile organic compounds (VOCs).

Automobile emissions catalysts are seeing both good and bad times in terms of market growth. In the U.S., growth is expected to be fairly flat, if not decreasing, because of the impact of the recession on automobile sales. However, offsetting slow growth in the U.S. are regulations coming into effect in 1993 in Europe that will lead to at least a doubling of the market there and about 15% growth overall.

Automotive catalysts are expected to grow from about 42 million catalytic units to about 49 million units worldwide by 1993, says Willem Groenendaal of Strategic Analysis, a Reading, Pa.-based market consulting firm. Europe, which accounts for about 9 million of the 42 million units currently sold, is expected to grow to about 20 million units by 1994 or 1995. This would make the European market about equal in size to that in the U.S.

About 75% of the value of auto emissions control catalysts is contributed by the precious metals, says Groenendaal. Precious metals in the platinum group, including platinum, palladium, rhodium, and ruthenium, are used in automotive, environmental control, chemical processing, and petroleum catalysts. Automotive catalysts, generally consisting of precious metals supported on ceramics or metals called monoliths, account for the largest usage of platinum group metals. Catalyst producers are always under pressure to produce more cost-effective products, and major targets are a reduction in the amount of precious metals used and an increase in the amount recycled.

According to the Department of the Interior's Bureau of Mines' figures for the first half of 1991, 9200 kg of platinum were sold in the U.S. for automotive uses. This market also consumed 1319 kg each of palladium and rhodium. Chemical processing catalysts used a total of about 1369 kg of all three metals, whereas petroleum catalysts used about 1782 kg of platinum and palladium.

The worldwide automotive catalyst

market is dominated by five competitors—Johnson Matthey, Allied-Signal, Engelhard, Degussa, and Davison Chemical. Johnson Matthey, based in Wayne, Pa., has the largest market share of about 30%. Both Engelhard and Allied-Signal's Automotive Catalyst Co. in Des Plaines, Ill., estimate their market shares to be between 20 and 25%. Degussa, with U.S. headquarters in Ridgefield Park, N.J., has less than 10% of the worldwide market, and Davison is a smaller player, supplying catalyst powders for coating auto catalyst monoliths.

"Engelhard is probably the most strategically located automotive catalyst manufacturer in the world," says James Healy, Engelhard's group vice president and general manager for environmental catalysts. The company has plants in North America, Europe, and South Korea, and in Japan through a joint venture, Nippon Engelhard Catalysts & Chemicals. None of Engelhard's competitors has a plant or joint venture in Japan to make catalytic converters, says Healy. Although U.S. automobile sales have been dropping, Engelhard says its market share has grown with sales to Japanese manufacturers in the U.S. And, Engelhard is in the process of expanding capacity threefold at its plant in Germany to meet European market needs and has bought out the other half of its German joint venture, Englehard Kali-Chemie GMBH.

Allied-Signal started up a manufacturing plant in early 1991 in Florange, France, and has already had to double capacity, which is scheduled to come on line in the first quarter of 1992. The company, which had sales of $179 million in 1991, has also built a new development facility in Toulouse, France, along with an engine testing and customer development laboratory. The next move will be to open a technical center in Japan by January 1993.

Although reformulated gasoline regulations are expected to have little direct impact on catalytic converter design, other pressures from automobile manufacturers and Clean Air Act regulations will affect their design. "All of our product development activity, whether it be stationary source or mobile source, is shaped by legislation," says Jerry Summers, technical director at Allied-Signal.

New provisions are requiring that the life of the catalytic converter be doubled to 100,000 miles. Three-way conversion catalysts currently operate as an oxidation catalyst to remove hydrocarbons and carbon monoxide, and as a reduction catalyst to remove nitrogen oxides. Although the number of replacement units sold will decrease, explains Healy, this may be offset by the larger size of the converters and their use of more catalyst. Catalysts also will have to be active or poison-resistant and temperature-stable over a longer period of time.

Another restriction being placed on automotive catalyst development is the reduction of hydrocarbon emissions during the first few minutes after an engine is started. During this "cold start" period, in which a converter is not yet hot enough to act catalytically, about 80% of a car's emissions occur. Davison, like others, is working on an electrically

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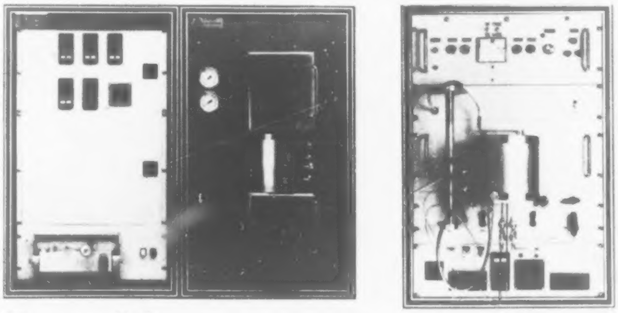

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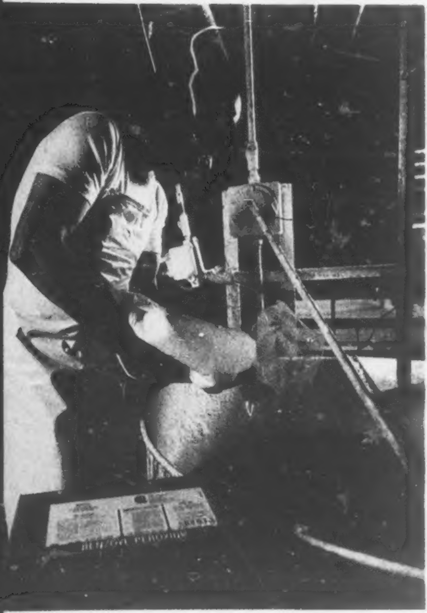
heated version of its Camet metal monolith to address a more rapid control of emissions, says James Maselli, vice president for R&D at Davison. Allied-Signal and Engelhard also are looking at resistively heated converters.

Other approaches are a close-coupled catalyst, explains Healy, in which the converter is placed close to the engine or reducing the temperature at which the catalyst becomes active. Currently, typical under-floor catalysts become active at about 250 to 300 °C, he says. Yet another being worked on by Engelhard and Allied-Signal are systems to absorb or trap hydrocarbons from cold exhausts. When the system later heats up, hydrocarbons are released onto a hot, active catalyst. Engelhard is at the point, says Healy, where it can work with automobile firms to test the feasibility and limitations of its technology.

"Lean burn" applications to enhance fuel economy and lower hydrocarbon emissions also are presenting challenges for catalyst producers. Operating auto engines at an air-to-fuel ratio of about 20, or lean of the stoichiometric ratio of 14.7, increases nitrogen oxide levels. Traditional noble-metal catalysts are very ineffective at converting high levels of nitrogen oxides, says Summers, and so new technologies using materials such as zeolites are under development by Allied-Signal as well as by other companies. Catalyst producers also are looking at catalyst development for vehicles that run on alternative fuels, such as natural gas and alcohol mixtures, and have their own unique emissions profiles.

The market for controlling emissions from diesel engines is also growing, as new restrictions come into effect by 1994. Engelhard has focused specifically on this $150 million U.S. market for about two years, says Healy, and believes that its new proprietary catalyst developments will give the company a 40 to 50% market share in North America. This initial thrust has been so successful, he adds, that Engelhard is now focusing on Europe and Japan and has set up diesel engine labs in Germany and Japan, besides its lab in New Jersey, to support this effort. Smaller, yet growing, markets include off-road vehicles such as fork lifts and mining equipment.

Many catalyst producers are extending what they have learned in automotive emissions control to stationary source emissions control. There are four major targets for stationary emissions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Peroxide catalyst blend added to mix for extruded polystyrene

control—carbon monoxide, nitrogen oxides, VOCs, and sulfur dioxide—and different catalytic strategies involved. In addition, plants may consider other approaches such as process modifications or changes in formulations to prevent emissions. But for boilers, turbines, heaters, and other fuel-consuming units, suppliers say it is unlikely that catalytic controls can be avoided.

The U.S. market for industrial emissions control is estimated at only about $80 million in 1991, according to Catalyst Group, but it is forecast to grow as large as $1 billion by 2000. With the market still in its infancy, rapid growth will be driven largely by new regulations under the 1990 Clean Air Act in reducing pollutants related to ozone, smog, and acid rain. Along with the rapid growth in the market, the number of suppliers is expected to expand. California, with the most stringent standards in the country, leads in actual sales of stationary emissions controls, and producers watch what is happening there as a sign for what will happen elsewhere.

Healy sees two primary segments—small and large process industries looking for VOC reduction, and power generation units in utilities, industrial plants, or refineries. Both segments have potential growth of 30% or more over the next five years, once regulations are put into effect. A variety of other niche market applications are opening up in smaller boilers and cogeneration units or in small and medium-size spray painting, printing, and textile drying operations.

Currently, stationary emissions control technologies are much different from automobile emissions control. Development goals include high reduction activities, selectivity, and reaction efficiencies for specific contaminants, especially in the area of VOCs. Emissions control catalysts must also be resistant to poisoning from various contaminants as well as being durable and having long lives. Catalyst suppliers are seeing some demand by customers for service because plant operators are not necessarily interested in operating,

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maintaining, replacing, or disposing of emissions control catalysts.

A dominant technology is selective catalytic reduction (SCR) for nitrogen oxides formed at high temperatures in the combustion of fossil fuels. SCR processes react ammonia with nitrogen oxides in the presence of a vanadia-titania catalyst to form nitrogen and water. The Japanese lead in this technology, because regulations went into effect for stationary sources in Japan during the 1970s.

Similarly, Germany has adopted strict standards for coal-fired power plants and licensed much of the technology in use from the Japanese. The market in both Western and Eastern Europe is poised for growth if these standards are adopted by other countries as well. In the U.S., the SCR market may grow from a small base to a few hundred million dollars within a few years as regulations expand. Companies trying to gain position in the U.S. market include Engelhard and Davison Chemical.

Davison's Synox technology is a base-metal catalyst system aimed at nitrogen oxide removal in utilities while trying to avoid SO_2 conversion to SO_3. Like other SCR catalysts, it is based on vanadium on titania and operates at temperatures between 300 and 400 °C. But, unlike typical SCR catalysts, the company says it has a higher activity and selectivity. The company also markets a system developed by Noxso Corp., in which W. R. Grace holds an equity position. This technology simultaneously removes nitrogen oxides and sulfur oxides from utility flue gases. It is based on a continuously regenerable sodium carbonate on alumina adsorbent. In fact, a majority of sulfur oxide removal systems are based on adsorbents, and effective catalytic systems have yet to be developed.

Davison's Camet product line of metal monolith catalysts includes a precious-metal system for simultaneously removing nitrogen oxides and carbon monoxide through an oxidation process. However, in general, precious-metal catalysts cannot handle all stationary emissions problems well since they are easily poisoned by sulfur. Therefore they are used in niche applications. Davison's catalysts are targeted at engine exhausts, gas turbine preburners, cogeneration plants, and VOC solvent incineration, among other applications. Engelhard says it has developed a carbon monoxide oxidation product that tolerates high sulfur levels as well as other precious-metal emissions catalysts aimed at VOC control.

Engelhard is a small player in the SCR market, but it is taking another approach toward nitrogen oxide reduction using its proprietary zeolite technology in some smaller applications, such as process boilers and cogeneration units. An advantage of the zeolite catalysts is that they have fewer disposal problems, says Healy, and can operate at temperatures about 100° C higher than SCR catalysts. The ability to operate at higher temperatures avoids costs associated with heat exchange systems needed for SCR.

Another approach to nitrogen oxide reduction is targeted at its initial production. Catalytica is working with Tanaka Kikinzoku Kogyo of Japan in developing a catalytic combustion technology for electric power generation by natural-gas turbines. The proprietary technology has demonstrated emissions well below current and proposed regulatory limits without any exhaust gas after treatment, says Catalytica. Nitrogen oxide emissions have been reduced to less than 1 ppm, and carbon monoxide and hydrocarbon emissions have been reduced to less than 10 ppm.

Engelhard calls its catalytic combustion technology "catathermal combustion." These precious-metal catalytic systems are aimed at getting the same fuel efficiency out of a turbine, says Healy, but while operating at a temperature below 1500° C. It is above that temperature that atmospheric nitrogen reacts to form nitrogen oxides.

Allied-Signal recently has started its own efforts in industrial emissions controls, but it is not a player in the SCR market. In 1990, its industrial catalysts division had sales of about $1 million, but the company is anticipating reaching sales of about $40 million by 1995. One area it is focusing on is VOC controls. Since emissions-control catalysts containing precious metals alone would be strongly poisoned by halogens and insufficiently active, Allied-Signal has developed a new family of catalysts. Its halohydrocarbon destruction catalysts, a combination of base and precious metals, will convert a wide range of halogen-containing hydrocarbons to harmless products, says Summers. □

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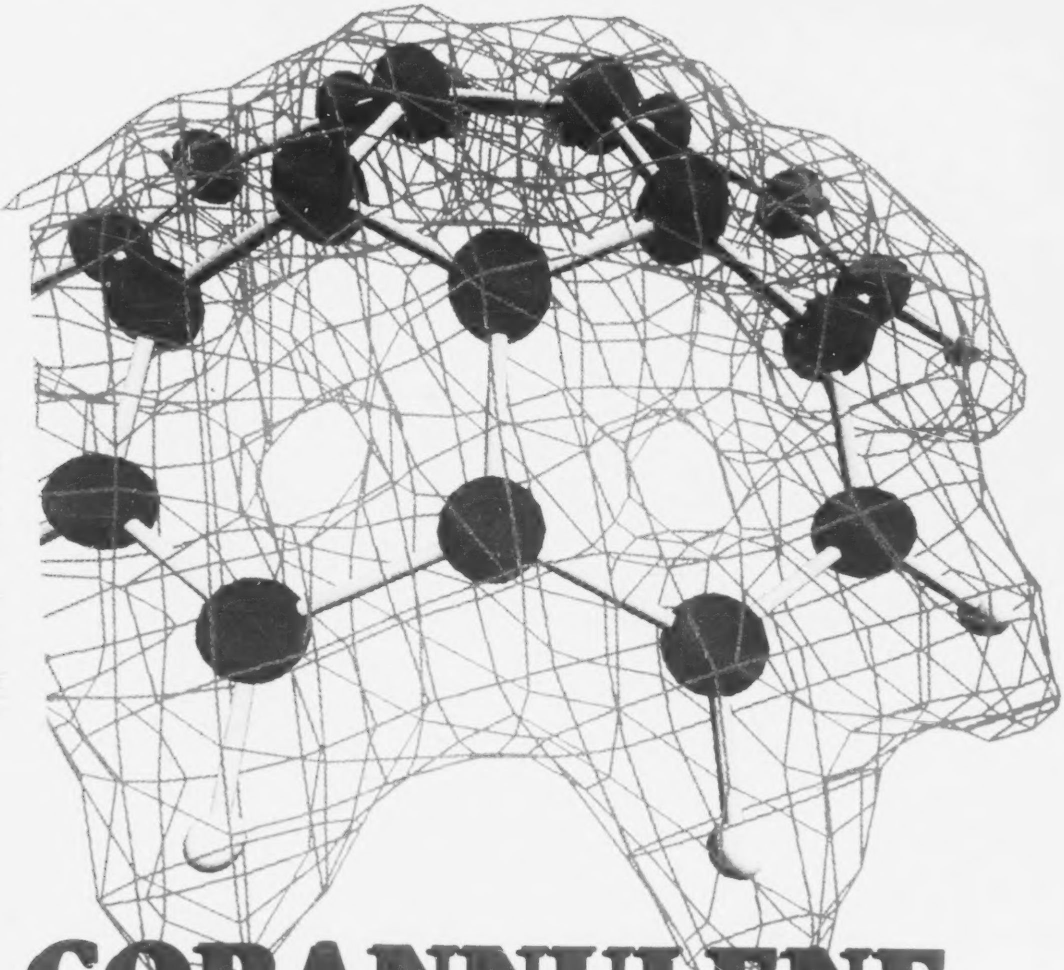

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Bowl-shaped hydrocarbon is
surprisingly flexible
Page 27

CHEMICAL & ENGINEERING NEWS
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NEWS OF THE WEEK

- Chemists at Pennsylvania State University have found that "metallo-carbohedrene" clusters containing eight titanium atoms and 12 carbon atoms are remarkably stable, promising significant expansion of the molecular clusters field. **Page 4**
- Space shuttle flight scheduled for next week will carry ATLAS-1, the first in a series of missions designed to probe the chemistry and physics of the atmosphere. **Page 5**
- FDA launches effort to speed up approval of biotechnology drugs, hiring 50 new reviewers and appointing a new head for the responsible unit. **Page 6**
- A strategic, long-term vision for civilian science and technology, calling for transfer of funding from defense R&D, is outlined in report by House Committee on Science, Space & Technology. **Page 6**

COVER: Computer graphic image shows curved corannulene molecule with carbon in blue, hydrogen in yellow, and electron density represented by red network. Graphic produced by Kim Baldridge of San Diego Supercomputer Center

Volume 70, Number 11
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NEWS FOCUS

Union Carbide's involvement with the 1984 methyl isocyanate accident at its Bhopal plant continues as an Indian court issues criminal charges against the company and former chairman Warren M. Anderson. **Page 7**

BUSINESS

Companies are confronted with a big leap in costs of health benefits for retirees, the result of a new accounting standard that requires setting aside millions, or even billions, of dollars to cover these benefits. **Page 17**

International Trade Commission is considering changing to a new format for its annual synthetic organic chemicals report based on the Harmonized Tariff System. **Page 22**

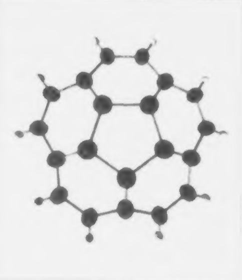
GOVERNMENT

Economic recovery, OSHA reform, and energy legislation are some of the issues being debated and discussed by Congress in this election year. **Page 24**

SCIENCE/TECHNOLOGY

A biennial conference, "Chemistry as a Life Science," tracks the intensifying involvement of chemistry at the interface with biology. **Page 29**

COVER STORY



Recent studies indicate that the bowl-shaped corannulene molecule is not rigid at room temperature, as was previously thought, but instead is extremely flexible. Page 27

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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Employment guidelines

As a long-time advocate of the ACS Professional Employment Guidelines, I regret that no mention of this pertinent document was made in the letter by Nelson Marans (C&EN, Jan. 27, page 2), in which he related a 30-year-old incident of a student who accepted an expense-paid transcontinental interview trip solely in order to visit his parents in a nearby city.

The very first statement in Professional Employment Guidelines addresses this situation quite completely: "The prospective employee should apply only for positions in which there is a serious interest, a belief that job qualifications are met, and a willingness to consider acceptance of an employment offer."

Approximately 18,000 copies of the current edition of Professional Employment Guidelines were distributed in 1989, mostly to employers and to chemistry departments. Perhaps these guidelines should be distributed even more widely and made required reading for chemistry students, as well as their prospective employers. Of course, mere reading about the ethical standards that ACS expects of chemists will not automatically result in the elimination of unethical behavior. But it would be a step in the right direction.

Donald J. Berets
Stamford, Conn.

Amino acid derivatives

We at Synthetech Inc. read with keen interest the article on custom chemicals (C&EN, Feb. 3, page 25). However, we disagree with the closing paragraph, which implies that amino acid derivatives belong to a technology area not available in the U.S., and that one has to turn to Japan for these products.

Although we do not dispute the capabilities of Japanese or other overseas producers, we find this comment interesting, because we are exporting bulk quantities of protected amino acid derivatives from the U.S. to Japan, as well as to various countries in Western Europe. The rapidly growing customer base for our wide range of peptide building blocks includes major pharmaceutical companies, leading custom peptide firms, catalog houses, and research institutions worldwide. Our product quality, responsiveness to customer needs, and competitive pricing have earned us a place as a leading niche player in this emerging growth area. Synthetech is also the world leader in multikilo production of novel synthetic amino acids of exceptional chiral purity, for use as building blocks in therapeutic peptides.

Although it may appear to some industry observers that domestic expertise and capabilities for a wide range of fine chemicals and intermediates are no match for Japanese and European sources, it would be premature to include amino acid derivatives in this category. At least, not as long as Synthetech is growing and thriving.

M. (Sreeni) Sreenivasan
Chief Operating Officer
Synthetech Inc., Albany, Ore.

Energy taxes

I read Robert C. Amero's letter (C&EN, Feb. 17, page 3) on energy taxes with great interest. Although Amero is not the first to suggest imposing a gradually increasing tax on imported petroleum, the idea has much merit; however, my purpose here pertains to some of his statements.

One passage reads, "Second, people began to reproduce like locusts or lemmings. World population had been less than half a billion for eons; today it is about 7 billion and growing rapidly." Hyperbole for the most part. According to Table A.1 on page 181 in "World Development Report 1991," the estimated mid-1990 world population was 5.298 billion. The global-averaged population growth rate was 1.6% per annum, with minimum and maximum annual rates of 0.5% and 3.2% for Organization for Economic Cooperation & Development members and sub-Saharan Africa, respectively. At annual growth rates of 0.5%, 1.6%, and 3.2%, compounded instantaneously (for example, exponential growth), it would take 55.7, 17.4, and 8.7 years, respectively, to reach 7 billion people. When one examines exactly who is reproducing most rapidly, the terms "locusts" and "lemmings" appear to characterize people in the poorest developing countries. This is no less than slander and does not serve any useful purpose. My work involves international development, and one has to be very careful with the words that one uses, hence my sensitivity to what Amero probably did not recognize in his prose.

I also take issue with Cosby Field's statement (cited by Amero) about human slaves being absent from the engineer world, as if human relations would suddenly improve as a result of "cheap" ma-

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Companies Face Big Jump in Costs of Health Benefits for Retirees

■ ***New accounting rule requires firms to set aside millions of dollars to fund benefits; future retirees may lose some benefits***

Marc S. Reisch,
C&EN Northeast News Bureau

The costs of keeping retirees healthy is about to bring a big and unwelcome jolt to corporate finances. Because of a new accounting requirement, companies that provide health care benefits to their retirees will have to set aside millions, even billions, of dollars on their books to account for the costs of these benefits.

Those charges will come directly out of corporate net earnings. And though they will not immediately affect cash flow, they force companies to disclose an obligation that may in the future affect dividends, their ability to finance capital spending, and research and development funding. The charges also will include annual costs to companies that are higher than they are now to provide retiree health protection.

Even with these new financial arrangements, future pensioners, especially younger and newer employees, cannot relax. The set-asides will not necessarily provide health care for future retirees at the same levels that have been customary to date. Nor will they guarantee that corporate funds will be available to pay those benefits in the future if a company goes bankrupt. No law requires a corporation to establish separate funds for retiree health care costs as they are required to do to pay for pension benefits, though some are doing so to a limited extent.

In fact, the new accounting rule, known as financial accounting standard 106 (FAS 106), requires only that companies anticipate costs for retirees' postretirement benefits, other than pensions, on the companies' books. Although the standard includes other benefits such as life insurance, the rule focuses principally on postretirement health care benefits. The Financial Accounting Standards Board (FASB), Norwalk, Conn., the chief rule-making body for corporate accounting standards, issued the new rule in December 1990. Most corporations are required to adopt the rule no later than 1993.

This change in accounting for retiree health benefits reflects the impact of spiraling health care costs in this country on both employers and employees. Younger employees will end up receiving less generous retiree health benefits, and at higher personal cost, than will their older colleagues already at or approaching retirement.

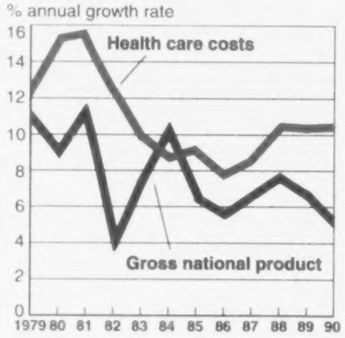
Many companies are already making moves to contain the costs they have to meet for retiree health benefits. Some are requiring retirees to contribute to the cost of health insurance. Others are eliminating postretirement health insurance coverage for employees who are just entering the work force and whose retirements are decades away.

David M. Sullivan, an accountant at FASB, says the rule requires companies that provide retirees with health benefits to account for the benefits throughout the working life of the employee. FASB considers those benefits a form of deferred compensation, and its rule requires corporations to take a charge on their books for them as they are incurred. Most corporations that now provide retiree health benefits account for them only as they are paid out.

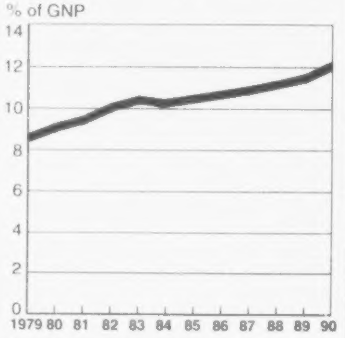
For instance, Dow Chemical paid out $53 million before taxes to provide current U.S. retirees with health care benefits in 1991, says a company spokesman. Under the new rules, which Dow plans to implement in the first quarter of 1993, Dow estimates it will have to set aside close to $155 million annually on its books to pay for current retiree health costs, and also to provide a reserve for its obligation to employees who will retire in the future. Dow no longer will account for retiree health care purely on a pay-as-you-go basis. It will effectively switch to an accrual accounting method, which will force the company to build up a cash reserve on its books to recognize employees' claims to future health care benefits.

However, the big impact of the FASB rule is that Dow will be required to take a one-time charge of about $1.5 billion (appearing on the books as a $1

Health care costs rising faster than GNP . . .



. . . and now exceed 12% of gross national product



Source: Department of Health & Human Services, Health Care Financing Administration

New rule may dampen R&D, capital spending

Most people may think of financial accounting standard 106 (FAS 106) only as an accounting rule involving very large numbers to account for retiree health benefit costs now and in the future. However, the rule could affect a company in a number of ways—some adverse and some beneficial.

For instance, cash flow may not be affected now, but the reserve on company books eventually will have to be paid out to satisfy "an ever escalating health care bill," says Scott Sprinzen, senior vice president and analyst of credit rating agency Standard & Poor's. The provision for retiree health benefits could ultimately limit funds available for dividends, R&D, and capital spending if health costs increase too fast, says Sprinzen. And FAS 106 in time could even hurt some companies' credit ratings, if companies cannot control costs, he adds.

On a separate financial note, Patricia L. Wilson, a principal with employee benefits consultant A. Foster Higgins, Philadelphia, suggests that FAS 106 will affect the cost of goods and services and therefore the competitiveness of companies with costly benefits plans. Somehow companies will have to come up with the money for retirees' health benefits. In 1990, U.S. car makers added $1086 on average to the price of a vehicle to cover health care costs for employees, about half of whom are retired. That is about $500 more per vehicle than Japanese competitors build into the price of their vehicles for the same purpose, according to the University of Michigan's Transportation Research Institute, Ann Arbor, Mich.

Postretirement health benefits have helped companies reduce their work force by enabling them to extend benefits to early retirees, notes Robert Cirkiel, senior manager of the group compensation and benefits unit of accounting firm KPMG Peat Marwick, New York. Companies promise to cover health benefits for retirees under 65 and their dependents until the retirees become eligible for Medicare. The government's General Accounting Office estimates corporate liabilities to provide health care benefits for retirees under 65 will amount to $99 billion.

But while extending benefits to early retirees to reduce the work force, and continuing to extend coverage beyond Medicare for older retirees, companies may build up enough of a liability on their books to make a purchaser of a company think twice. The purchaser would have to assume the costs for continuing to fund retiree health benefits. As a result, it may pay a lower price for the firm to account for those costs. Conversely, shareholders would receive less money if their company were sold because of the health care liability to retirees.

Michael B. Sirkin, a principal with accounting firm Price Waterhouse, Los Angeles, says, "Some smaller takeovers we evaluated fell apart after we evaluated the promises the takeover targets made to employees."

billion after-tax charge) in the first quarter of 1993 to set its books right. That one-time charge will allow the company to catch up to the reserve it should have on its books to fund current and future retiree health care costs. If that charge would have been taken in the first quarter of 1991, it would have resulted in a roughly $500 million net loss instead of a $578 million net profit.

Dow has not yet decided if it will establish a separate fund in which to set aside accrued dollars for retiree health care. Heino Zell, Dow USA director of compensation and benefits, says Dow executives are mulling over funding mechanisms now. Just between 1988 and 1991, Dow's costs for retiree health care benefits on a pay-as-you-go basis rose 36%, from $39 million in 1988 to $53 million in 1991.

Current Dow retirees need not worry. Zell says they will continue to get full coverage of benefits, which include health costs not covered by Medicare, the federal government's insurance program for retired senior citizens. However, those who retire from Dow USA after Jan. 1, 1993, will only get full coverage beyond Medicare if they worked for Dow at least 30 years. And the newest and youngest employees who join the company after Jan. 1, 1993, will receive no postretirement health care benefits. Instead, says Zell, they can voluntarily contribute to a tax-free fund. Dow will make matching contributions out of which employees may pay health care costs when they retire. "Long term we are getting out of post-Medicare supplementary benefits," says Zell. The move is intended to limit Dow's long-term liability.

Dow will match employees' after-tax contributions up to $30 a month, in what it terms a retirement health care assistance plan. Dow is waiting for an Internal Revenue Service go-ahead on whether the plan, as the firm envisions it, would be tax-free. Dow's contribution would become available only upon an employee's retirement. Employees who leave to take another job would receive lump sum returns of their contribution, but without Dow's contribution. "If someone leaves Dow," says Zell, "we don't have an obligation to support them."

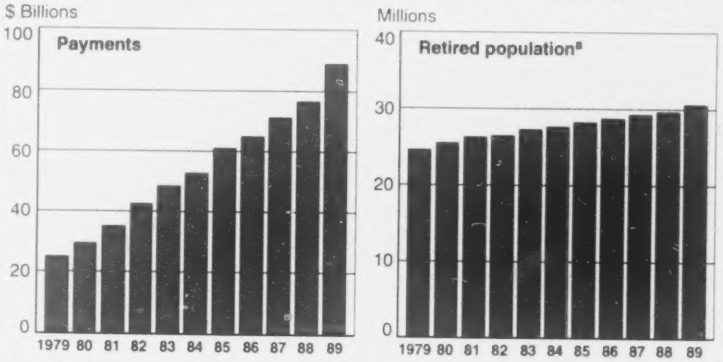
Dow employees who retire after Jan. 1, 1993, without 30 years of service, or employees who join Dow after that date and don't put in enough years to retire with a large health care assistance fund, may not have ample coverage for retirement, acknowledges Zell. But "we are just committed to help them for the time they spent with Dow," he says.

Dow provides just one vivid example of the changes FAS 106 is forcing corporations and their employees to confront. The government's General Accounting Office (GAO) estimates all corporate liabilities on a pay-as-you-go basis for health care benefits to cover 9 million retirees along with spouses and dependents was $11.4 billion in 1991. These numbers include early retirees under the age of 65 and dependents. Had FAS 106 been in effect in 1991, corporate costs and charges would have reached $42 billion. GAO further estimates companies' 1991 accrued retiree health liabilities at $335 billion.

Past, present, and projected increases in health care costs for retirees have to be understood within the framework of huge overall increases in national health care costs. According to the government's Health Care Financing Administration (HCFA), Americans' health care costs increased 178% between 1979 and 1989, from $217 billion to $603 billion. The numbers include all public and private spending. HCFA projects national health care costs will reach more than $1.6 trillion by the year 2000.

Spending on Medicare was up 266% from $24 billion for plan participants over age 65 in 1979 to $88 billion in 1989. HCFA projects Medicare spending for participants over 65 will reach $273 billion in 2000.

Medicare payments growing faster than retired population



a Enrolled in Medicare and age 65 and older
Source: Department of Health & Human Services, Health Care Financing Administration

Certainly increases in costs have affected everyone: National health care spending has grown from slightly less than 9% of the country's gross national product in 1979 to over 12% in 1990. HCFA projects it will reach 16% of GNP by 2000. However, the effects of increased costs have been more pronounced on the population over 65 than for the population as a whole. That is, in part, because the over-65 population is growing faster than the general population. U.S. population grew roughly 10% between 1979 and 1989 to 257 million, whereas the population over 65 grew 22% to 30 million.

It is no surprise then that Medicare costs have grown from 11% to 15% of U.S. annual health expenditures between 1979 and 1989, even though the government has instituted procedures to control Medicare expenditures. And it is no wonder, too, that employers are increasingly concerned about their responsibilities to retirees for the costs Medicare does not pay. Robert Cirkiel, an actuary and senior manager specializing in health care at the accounting firm KPMG Peat Marwick, New York, says employers have good reason to be concerned. Their costs are set to rise as the federal government cuts back on Medicare benefits, the U.S. population continues to age, more people take advantage of medical care, new and more costly medical technology becomes available, and ever more expensive wonder drugs come onto the market.

But is the answer to spiraling costs, like Dow's, to eventually end traditional health care insurance for retirees? Du Pont's Jack Stair, finance treasury senior consultant, thinks not. "The cost, not the program, is the problem," he says. Setting up health savings plans as Dow proposes to do, only shifts the costs to the retiree who may or may not have enough money saved up to cover his or her costs, says Stair. Du Pont plans no change in retiree health benefits for current or future retirees. They will continue to receive coverage for out-of-pocket expenses that Medicare does not cover.

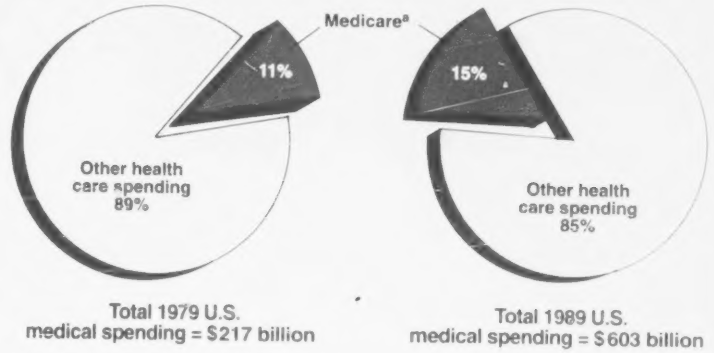
Du Pont advocates a national solution to the spiraling costs of medical care, says Stair. There is just so much one company—even one as large as Du Pont—can do to limit medical costs, he adds. However, Du Pont is not hoping for a federal program to provide national medical insurance, such as the one Canadians have had for a number of years. He believes that such a program would dole out benefits with the compassion of the IRS, at the speed of the post office, and at Pentagon prices.

Instead, Stair suggests that Congress act on such matters as medical billing practices and insurance company practices to help control medical costs. An insurance tax credit, which President Bush recently proposed to allow all Americans some degree of health coverage via tax credits, also would go a long way to controling medical costs, he says.

Du Pont accounting consultant Roderick K. Davis says the company currently spends about $250 million per year on postretirement health care benefits. When Du Pont adopts FAS 106 beginning in the first quarter of 1993, it will have to set aside annually between $450 million and $700 million to account for current and future obligations to retirees. The company currently has no plans to separately fund retiree health care benefits.

But again, like Dow, the biggest wallop for Du Pont will come as a one-time charge of from $4.6 billion to $6.2 billion (the equivalent of from $3 billion to $4 billion after taxes). That is the largest "transition obligation" recorded to date among chemical industry companies. General Motors' obligation of from $16 billion to $24 billion before taxes is so far the largest transition obligation any company has announced. If Du Pont had taken its transition charge in the first quarter of 1991, net income of $590 million would have become a net loss of from $2.4 billion to $3.4 billion.

Medicare is rising share of total medical spending



a Age 65 and older. **Source:** Department of Health & Human Services, Health Care Financing Administration

General Electric already knows the cost of complying with FAS 106. In 1990, before it adopted the new rule, GE paid $249 million for retiree health benefits. After it adopted the rule in 1991, the company's annual contribution for current and future retiree benefits rose to $279 million.

The company also took a one-time transition charge of $1.8 billion after taxes ($2.7 billion before taxes) to account for health benefits payable to current and future retirees. GE had already set aside $1.5 billion before taxes on its books prior to its adoption of the new accounting rule, so the total now held aside on its books adds up to $4.2 billion. The catch-up charge effectively resulted in a retroactive net loss of $800 million for the first quarter of 1991—GE's first quarterly loss in more than 20 years.

But despite the enormous charges, GE has actually increased the benefits it now pays to retirees. The increases in both daily benefits for hospitalization and lifetime maximums were the result of a new contract the company negotiated with its unionized employees in June 1991. GE automatically extends nonunionized labor the same benefits it negotiates with unionized employees. A GE spokesman says that the company has the same concerns as everyone else. However, its bargain with employees is a "calculated risk." The contract with unionized employees comes up for renewal at the end of June 1994. Since health benefits are subject to negotiation, he says, benefits for retirees can change.

Can companies change postretirement health care plans? Benefits attorney Linda E. Rosenzweig, of Epstein, Becker & Green, Washington, D.C., says yes. An employees' rights to benefits after retirement can change up until retirement as long as the company clearly reserves the right to do so.

To date, few companies besides GE have adopted the new accounting rules. Benefits consulting firm A. Foster Higgins & Co., Philadelphia, says that about half of all employers who provide postretirement health care benefits have not decided when they will adopt FAS 106. An informal C&EN survey finds that chemical producers such as Ashland, FMC, and W. R. Grace have made no decision on how to comply with the accounting standard. However, Monsanto, Morton International, Arco Chemical, and Cabot have come to some determinations.

Monsanto says it has accrued aftertax health care obligations to current and future retirees of about $1 billion. After-tax obligations for Morton International are in the $100 million range, Arco Chemical's are about $30 million, and for Cabot they are about $28 million. Although two of the four have yet to make any change in postretirement health benefits, Morton International and Cabot have made changes.

Morton International recently changed its plan so that full benefits go to those with the longest service. Cabot's corporate staff controller, Mario J. Cornacchio, says FAS 106 forced the company to review health care costs and it has decided to put a cap on Cabot's contribution to active employees' and retirees'

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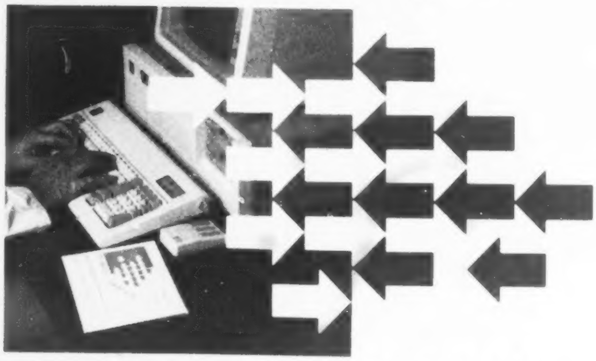

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health care plans. "Employees and retirees will shoulder higher costs in the future," says Cornacchio. The company does not plan to separately fund its health care obligations to employees now, though it is considering this for the future. "The warning is out," adds Cornacchio. "Just as people save for retirement by putting aside money to supplement Social Security, they will have to put aside money for health care, too."

Tax-deferred options allowing employees to put aside money for the cost of health care in retirement are limited, notes KPMG Peat Marwick's Cirkiel. Voluntary Employee Beneficiary Associations and so-called 401H plans (a supplement to a retirement account) allow limited tax-deferred employee and employer contributions. But given the national debt, Cirkiel notes that the government is loathe to give tax breaks at this time. He also suggests that corporations consider buying life insurance policies for current employees. Benefits paid out could fund retiree group health costs, he suggests.

However, Patricia L. Wilson, a principal with A. Foster Higgins, believes that future pension benefits for today's employees will be so good that employees will be able to pay a significant portion of their health benefits. It is a common belief, she says, that people accumulate capital when they work and deplete it in retirement. However, today's large-company employees will retire with sound defined pensions as well as the proceeds from their profit-sharing 401K plans. And given the additional value of Medicare benefits and Social Security, most retirees from large firms will be well off, she says. Employers must encourage their employees to think of their 401K plans "as a vehicle to pay for a portion of their retirement health care benefits."

Thus employees not only have to examine closely their retirement health care benefits, but they also must look closely at their pension benefits to be sure these benefits will help defray health care costs. Out-of-pocket health care expenses for the elderly rose from $1589 per household in 1961 to $3305 per household in 1991 in constant 1991 dollars. And although the $17.5 billion the elderly spent to pay premiums and other out-of-pocket expenses represented 11% of after-tax income in 1961, the $67 billion the elderly spent in 1991 represents 17% of after-tax income, according to Families USA, a Washington, D.C.-based nonprofit research group. "Medicare has helped our parents and grandparents, but despite Medicare, older Americans are today being squeezed much harder by health costs than during John F. Kennedy's time," says Ron Pollack, executive director of Families USA.

And today's workers "could retire without the benefits of today's pensioners," notes Michael B. Sirkin, a principal in the employee benefits services unit of accounting firm Price Waterhouse, Los Angeles. In a warning to both employers and employees, he says that "promises large companies make to pay benefits in the future are only as good as the companies' ability to pay. The value of those promises depends on the financial strength of a company." ☐

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CHEMICAL & ENGINEERING NEWS

C&EN

MARCH 23, 1992

NEWS OF THE WEEK

■ Senate hearing calls for immediate help by the U.S. for the science and technology establishment in the former Soviet Union. **Page 4**

■ Federal appeals court upholds ruling that municipalities must share Superfund cost of cleaning up landfills containing hazardous wastes. **Page 5**

■ U.S. has major problems in finding and appointing good scientific talent to top science and technology jobs in government, the National Research Council reports. **Page 5**

■ Air Products head Dexter Baker will retire, effective May 1, when he will be succeeded by current president and chief operating officer, Harold Wagner. **Page 5**

■ Two new findings in the properties and chemistry of buckminsterfullerene—unusual optical properties and C_{60} with a single iron atom trapped in its carbon cage—were disclosed last week. **Page 6**

■ Dow Corning, the biggest maker of silicone gel breast implants, is exiting the business. **Page 6**

COVER: Photo by C&EN's James H. Krieger

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BUSINESS

Phillips 66 is back on track with its plastics business following the explosion that rocked its Houston complex in 1989, but faces problems of modest plastics demand, lingering lawsuits. **Page 9**

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ICI's new bulk pharmaceutical plant in Puerto Rico reflects British firm's growing investment overseas and increasing production of higher value-added products. **Page 12**

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Proposed new, tighter definition for scientific misconduct offered by Health & Human Services advisory panel would include concept of intent to deceive. **Page 14**

SCIENCE/TECHNOLOGY

Program that reads scanned molecular images and interprets these images into printed chemical structure diagrams is now available commercially, promises to be a boon to storage and access of such scientific information. **Page 17**

Fate of Australian science and technology is at crossroads and needs decisive efforts from the new coalition government to safeguard its future, according to president of Royal Australian Chemical Institute. **Page 19**

BOOKS

"International Handbook on Chemical Weapons Proliferation," though lacking information related to the Persian Gulf War, will serve as reliable reference for those who need to focus on the issues involved. **Page 74**

INSTRUMENTATION '92

Pittcon '92, the 43rd edition of the Pittsburgh Conference & Exposition on Analytical Chemistry & Applied Spectroscopy, included over 900 exhibitors and focused on the future direction of instrumental analysis. Page 22

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600, TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr $105, 2 yr $189; outside U.S. 1 yr $141, 2 yr $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Academic future

It is certainly heartening to learn in the report, "America's Academic Future" (C&EN, March 2, page 17), of the importance that Presidential Young Investigators (PYIs) ascribe to undergraduate education. If, indeed, these people now carry that message back to their respective departments and institutions, and, more important, work actively to craft an environment that legitimizes faculty—including nontenured faculty—commitment to the nonresearch component of education, they will have performed an inestimable service to the advancement of science.

There is no inherent reason why the challenge cannot be met, and why the same intellectual energy that has served the U.S. research effort so magnificently cannot be as effective in addressing larger educational issues as well. The task will not be easy, because the culture that they describe is well embedded in academic departments, and because the needs and possible solutions in education are far more diverse than in the research arena. Unlike experimental or computational results, what works educationally in one setting may not work in another; adaptability, not replicability, is the keyword.

Here are some suggestions for making a change. First, doctoral education can emphasize to graduate students their responsibility as future teachers, even if their professional positions after degree completion do not take them into academic environments. Defining teaching as facilitating active learning by students, every chemist has both an opportunity and a responsibility to be a teacher. Accordingly, the notion that graduate students belong only in the laboratory needs drastically to be modified. Happily, there are instances at a few Ph.D.-granting institutions that show early signs of change in this attitude.

Second, it is gratifying to learn that PYIs are concerned about rewarding nonresearch activities, especially in the context of tenure and promotion. However, we still need to develop and agree upon the means to appraise the effectiveness of these efforts that incorporate principles of rigor analogous to those used in evaluating research. Otherwise, teaching is still likely to suffer characterization as a second-class activity. The argument that teaching (usually referring to traditional classroom teaching) cannot be evaluated, especially externally, is self-defeating. Difficult, yes; impossible, no. We just haven't figured out how to do it meaningfully. Taking advantage of what is known about learning, chemists can indeed unravel the enigma of evaluation.

Third, in addition to competitively reviewed and awarded external grant support for scholarly educational efforts, invitations to present seminars in academic departments on educational advances can contribute substantially to legitimizing and encouraging faculty members to commit at least part of their energies to education. Approbation by one's peers, of which invitations to speak are an example, is probably exceeded only by money as a stimulus for further engagement in a useful endeavor.

Fourth, because the criteria of scholarly research achievements for tenure and promotion are part of an almost universally accepted canon at institutions of higher learning, the opportunity exists for a disciplinary restructuring of that canon to include educational contributions. Within an institution, academic administrators can do this only to a highly limited extent, and individual departments might feel constrained from acting because of concern either about faculty dissension or that faculty members who object might seek to leave for other settings more to their liking. The collective practitioners of the discipline, however, can make a difference, because it is they who set the comprehensive professional criteria. Here is an opportunity, for example, for the American Chemical Society's Committee on Science to take the lead by organizing efforts to build educational accomplishments into the tenets that characterize professional achievements.

An effective faculty member embodies attributes of both a teacher and a scholar. That is why, in 1970, the Camille & Henry Dreyfus Foundation introduced its Teacher-Scholar Awards Program. The balance between research and nonresearch professional accomplishments, however, is a highly personal choice, and for any individual may change over time—especially as human productive lifetimes increase. As long as high levels of excellence are maintained, these variations should be not merely tolerated but encouraged, at a minimum with the support mechanisms available to those who want to change research directions. It is

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Phillips Rebuilds Plastics Business Following 1989 Texas Explosion

Problems confronting company, however, are moderate plastics demand, pending lawsuits, and scrutiny from OSHA

Susan J. Ainsworth, C&EN Houston

When an explosion and fire rocked Phillips 66's Pasadena, Tex., chemical complex in October 1989, it made no small impact on the U.S. plastics business. The blast crippled one of the largest polyethylene facilities in the world, shuttering roughly 18% of total U.S. capacity for high-density polyethylene (HDPE). The accident also brought Phillips' plastics business to a virtual standstill, because production facilities for polypropylene and K-Resin styrene-butadiene copolymers at Pasadena had to be idled for a short time.

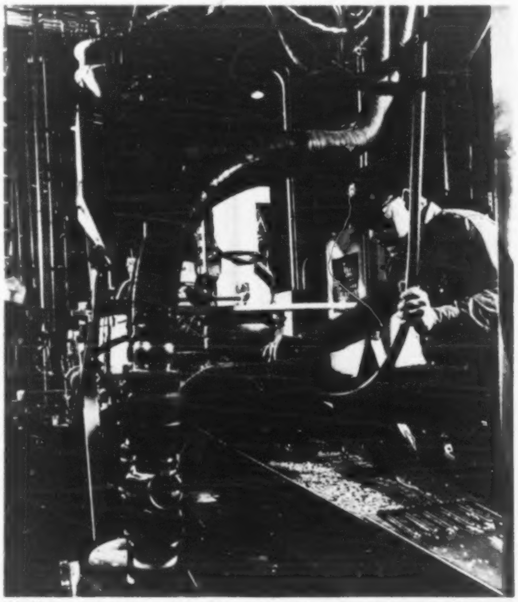
But now, Phillips 66, which is based in Bartlesville, Okla., says it has fully recovered from the blast. Bob Benz, vice president for plastic resins, says, "We've been two and a half years getting over the accident, and we think we're now back on track."

Over the past two years, the company has done more than rebuild its HDPE production capacity. Phillips 66 also has done some soul searching, deciding what operations really fit its long-term strategy. It has invested in recycling, and tried to sell some of its plastics businesses.

Unfortunately for Phillips, the company is getting back on track at a time when demand for HDPE remains moderate at best. "There's just too much supply," says Mark House, vice president for polymers at Houston-based consultants DeWitt & Co. After the boom years of 1987 and 1988, too many companies jumped on the bandwagon and added plants.

Although HDPE plant operating rates hovered around 98% in 1988, plants were running at only 88% of capacity in 1991. What's more, DeWitt anticipates rates to drop to between 80 and 82% this year and to "stay in that range for the next three years." House says he "fully expects to see some HDPE producers opt to sell their businesses or to shut down some of the higher cost production units in this period of rationalization." That would mean that newer, lower cost HDPE units would gain market share, which could be good news for Phillips.

Holding on to both market share and its customers was something that consultants said would be a chore for Phillips at the time of the explosion, but Phillips says it has fared well. The company was able to continue to satisfy its customers during the outage by purchasing plastics from its affiliate in Singapore to supply material under Phillips' name, says Benz. Those purchases have now stopped. Some in the company are amazed at the commitment from customers even after the time it took to rebuild the Pasadena facility—and during a recession.



Phillips technician checks recycled high-density polyethylene pellets as they enter dryer in final phase of production

Benz says Phillips will place 1.2 billion lb of polyethylene in the marketplace in 1992 with "less disruption than might be anticipated. The overcapacity in the industry is expected to be reduced through improved demand in the second quarter."

One saving grace for HDPE producers, including Phillips, is that total exports of their product from the U.S. broke a record in 1991, reaching 1.37 billion lb, representing 15% of 1991 production. That compares with 1990 HDPE exports of 921 million lb, or 11% of production that year, says House. He expects export growth to continue, but at a slower pace mainly because of the addition of capacity outside the U.S. Another plus for HDPE producers: "When times are tough, the packaging industry turns to HDPE because it is a cheaper alternative to paper, metal, and glass," says House. Still HDPE demand in the U.S. dropped roughly 1% in 1991, he adds. "While HDPE is fairly recession-resistant, demand did drop in response to the economy and changing packaging trends toward recycling and using less retail packaging."

With all the capital and time it took Phillips to rebuild its plastics business, it is surely keeping its fingers crossed that the plastics market will rebound soon. Rebuilding costs at the Pasadena site totaled $215 million last year, and Phillips has allotted a further $185 million in 1992 capital funds for completing the restoration work. The company has brought its HDPE back on stream in 600 million-lb stages, with the first starting up last June and a second last October. Both plants are operating near capacity. When a third train comes on stream by the end of fourth-quarter 1992, Phillips will have surpassed the 1.5 billion-lb-per-year HDPE nameplate capacity at Pasadena at the time of the accident.

Phillips' 480 million-lb-per-year polypropylene unit and its 270 million-lb-per-year K-Resin facilities were not damaged by the blast, but were shut down for about one week because of the outage of utilities they shared with the HDPE units. More significantly, those plants were idled later for longer periods of time, but for reasons unrelated to the 1989 accident.

Phillips has had more on its mind over the past three years than restoring the Pasadena facility. Last September, Phillips put its polyphenylene sulfide business on the block, but so far it has not found a buyer that is willing to pay the firm price it is asking. And last July, Phillips put its Bartlesville-based advanced composite business up for sale. It decided to cease operation of that business by year-end 1991, even though a buyer was not found. John VanBuskirk, Philips 66's senior vice president for plastics, says, "While Avtel products are technically proven and competitively priced, the time required to make them commercially successful is too long compared with other attractive investments and opportunities the company wishes to pursue."

Phillips 66 also decided to halt progress with its developmental resin, polymethyl pentene, for which it has a patent. It plans to hang onto the technology for a couple of years until the plastics market comes back and then decide whether to build a commercial plant.

The company did some investing as well. Last month it completed upgrade work on its polypropylene plant and it continues to develop new K-Resin grades at its Bartlesville pilot plant. In late December, Phillips expanded into plastics recycling, opening an 18 million-lb-per-year plant in Tulsa, Okla., to recycle HDPE bottles. In September 1990 the company became a controlling partner in a 75%-25% venture called Phillips Plastic Recycling Partnership with Partek Corp., a privately owned recycling company based in Vancouver, Wash. The partnership's Tulsa recycling plant now has purchase commitments for over 75% of the recycled HDPE it will produce during 1992. "With everyone in recycling attempting to expand markets for material sales, we are very satisfied with our immediate acceptance," says Tim Taylor, managing director of the partnership.

Recycling is something that all plastics producers "are being forced into—there's no economic incentive at this point," says DeWitt's House. Their customers are demanding access to recycled plastics to satisfy consumers who are increasingly demanding packaging that is perceived as environmentally friendly, he adds.

Demand for postconsumer recycled resin is down right now. Recognizing that, Phillips built its plant so it later can be expanded to produce 40 million lb per year. Right now, in many cases, prices for postconsumer recycled resin is higher than for virgin resin, notes Dennis L. Rohlting, the company's HDPE resins marketing manager. But that will change when one of two things happens: legislation is passed requiring increased use of postconsumer resins or the supply and demand balance of HDPE changes so that virgin HDPE prices will rise above that of recycle. "We can only guess which will happen first, but we probably won't see a change until 1994 or 1995." Still, he adds, "We have every reason to believe that this venture will be profitable over the long term."

Phillips 66 again will be a top U.S. producer of HDPE

Millions of lb	Annual capacity 1989	Annual capacity 1993ᵃ
Phillips 66	1550	1,800
Exxon Paxon	1300	1,800
Occidental Chemical	1270	1,710
Quantum Chemical	1750	1,690
Solvay Polymers	1160	1,440
Chevron Chemical	600	1,070
Union Carbide	650	900
Dow Chemical	525	600
Hoechst Celanese	350	425
Others	185	960
TOTAL	9340	12,395

a [illegible] Source: [illegible]

Worker collects resin samples from Phillips' Bartlesville K-Resin copolymer pilot plant

To further support its plastics operations through integration, late last December Phillips started a new olefins unit at its Sweeny, Tex., complex. The unit has a rated capacity to produce 1.5 billion lb of ethylene per year and 600 million lb per year of propylene. About 80% of the olefin unit's ethylene production is committed under long-term contracts.

Although Phillips seems to have its plastics business in order, it still has its share of problems. The company has not yet settled all of its civil litigation from the 1989 explosion. In addition, the Occupational Safety & Health Administration continues to scrutinize the safety of Phillips' operations. Late last month, the agency proposed some minor fines for failure to record on-the-job injuries in a government-required log at Pasadena. And the plastics business is also not immune to the turmoil caused by the major layoffs and reorganization set into motion by parent Phillips Petroleum. "Most employees have viewed Phillips as a company that would take care of you for the long haul. My concern is that these measures will sap that morale," laments one plastics manager.

Phillips is clearly trying to overcome these obstacles. It is also anxious to get the word out that it is no longer on the sidelines in the plastics game. "We have not enjoyed being out and we are back without any doubt," says Benz.

Meeting targets Eastern Europe investment fears

Increased cooperation in environment, markets, and investment between Western European and Eastern European chemical industries will lead to sustainable economic development in Eastern Europe, according to speakers at a conference sponsored by the United Nations Economic Commission for Europe, held in Warsaw earlier this month. More than 170 delegates, representing some 22 countries, attended the meeting.

The meeting saw the launch of a new initiative by Brussels-based CEFIC, the European Chemical Industry Council, for assisting environmental cleanup in the Eastern European chemical industry. The program, called EASTT, for Environmental Advisory Service for Technology Transfer, will involve volunteer western chemical companies advising counterpart eastern enterprises, at the behest of government ministries working with CEFIC.

And given the theme "sustainable development," and the recognition of the enormous work needed to be done to clean up the environment in Eastern Europe, the meeting thrashed out some guidelines that will form part of a pan-European contribution to the United Nations Conference on Environment & Development, scheduled to be held in Rio de Janeiro in June.

Richard D. Freeman, chairman of the "economic outlook" working party of CEFIC, and chief economist at British chemicals giant ICI, helped put the discussion into perspective.

In 1989, the latest year for which comparable data are available, the West European chemical industry was the world's largest, and was more than double that in Eastern Europe: roughly $350 billion in sales versus about $160 billion, according to Freeman. By comparison, North America, counting the U.S. and Canada, was about $300 billion.

Production in Eastern Europe is skewed toward basic chemicals. However, while Western Europe has been reducing its reliance on basic chemicals, Eastern European industry has not been. In part, that has been because of the availability of feedstocks, Freeman suggests, but that continuity also illustrates the strategic differences between companies in Western Europe and historical planning priorities in Eastern Europe.

There was no question at the conference about the potential importance of the Eastern European industry. As Daniel Janssen, president of CEFIC, pointed out, Europe at present—the 12 countries of the European Community—is made up of 340 million people, and with the seven countries from the European Free Trade Association, another 40 million. When Central and Eastern European countries are included in a future Europe, that count will zoom to nearly 600 million people.

CEFIC is encouraging formation of national Central European chemical federations, with an eye to their eventual membership. Applications from three federations—from Turkey, Poland, and Hungary—will be considered at CEFIC's annual meeting in Vienna in June. There is even the possibility of formation of a CEFIC-like organization operating throughout the Commonwealth of Independent States, pulling together the chemical industries in the different countries formed in the breakup of the Soviet Union.

According to Janssen and Hugo Lever, director general of CEFIC, government-to-government aid can benefit the development of infrastructure in Central and Eastern Europe—transport, communications, banking, and so on. On the other hand, the EASTT program is one step that western companies can take to help provide aid that will have a multiplier effect—encouraging and stimulating trade, service, technology transfer, and, ultimately, direct capital investment.

Under the new program, if a plant in Central Europe needs a certain energy modification, for example, owners of the plant will talk to the country's ministry about the investment, to determine, among other things, if the plant or enterprise is in the strategic plan for the nation. If it is, then the ministry would make a request to CEFIC for assistance. CEFIC would turn to a Western European company making similar products, which would conduct an audit of the eastern plant, to find out precisely what revamping or improvement technology is needed. The company or enterprise could obtain the technology through a variety of funding mechanisms, with the assurance that it would be getting the most appropriate, up-to-date technology.

Finding the appropriate way to participate in what he terms the "unfolding social and economic progress of Eastern and Central Europe" is a perplexing problem, says David Williamson, president of Du Pont's European operations. Nonetheless, it is a question that is being tackled in a systematic way.

"Each year we make capital investments of about $5 billion, and since we operate in 60 countries, investments are made all around the world every day. We have developed criteria to help us prioritize potential investments." Among the company's criteria: The overall economics of the investment should be attractive; the company must feel welcome, both nationally and locally; good quality people should be available in adequate numbers; and there should be a sound infrastructure. Even more important, he adds, there must be a legal and government framework that limits risk and facilitates business: "Laws governing investment and property ownership must be clear—vague assurances on these points are not enough.

"Guarantees to encourage private investment are far more cost-effective than traditional foreign aid," he says. "Western governments are reluctant to make large foreign aid commitments at the expense of domestic programs," in the present economic climate. "Partnership with private companies is a far more attractive—and more effective—route. As a rule of thumb, every job created direct-

Basic chemicals dominate East European production

	% of world production	
	Western Europe	Eastern Europe
Ethylene	32%	11%
Methanol	9	28
Chlorine	29	15
Fertilizers	13	30
Agrochemicals[a]	27	7
Pharmaceuticals[a]	30	4
Polyvinyl chloride	29	11
Polyethylene, low density	29	11
Polyethylene, high density	26	6
Polyethylene, linear low density	13	1
Polypropylene	31	6

a Percentage of world demand. **Source:** CEFIC (European Chemical Industry Council) ly by a foreign investor creates another three jobs to support the required infrastructure."

Government ministers from all the Central and Eastern European countries present at the meeting readily acknowledged the need to make changes encouraging foreign investment. It was clear, however, from presentations and from informal discussions in the corridors, that there is frequently a sizable gap in definition or attitude. What some authorities would call suitable action, corporate executives wouldn't. In light of their history, Central and Eastern European governments have made remarkably radical changes—changes demanded by potential investors. If western companies believe the changes don't go far enough, there is a danger these companies will feel betrayed.

Nonetheless, government authorities are trying to work to ease investment. For example, Thomas Kolaja, senior project manager in Poland's Ministry of Privatization, explained the Polish government's newly formulated approach to assisting privatization of its industry.

Last summer the country established 34 industrial sectors, and is working with western investment and banking advisers to prepare each sector for privatization. Among the factors to be considered, he points out, are upstream and downstream effects: They have to be kept in mind during privatization, in order to minimize disruptions in customer or supplier chains.

The ministry "seeks to clarify the market rules, so the private market and investors know what the rules are, and [to] make sure there is no confusion or conflict between agencies, for example," Kolaja says. "The only one who can really sell you a company is the Ministry of Privatization—we do the negotiations. Talk to us early in the process."

He concedes that judging environmental liability is a major problem. "In Central Europe, it is very difficult to give full, unlimited indemnity to companies. The budgets aren't ready to take the impact, but there is recognition of responsiblity. We can't give a blank check, but we'll fill it in for you, after we talk it through and both sides agree to the number."

Yet another means toward privatization has been launched in the Russian Republic, where a new stockholding corporation has been formed, called Roschimneft. All participating Russian chemical enterprises, and the government, have bought shares in the corporation, which will help promote marketing and distribution of Russian chemical products.

According to Vladimir Evsiukov, vice president, and Alexander Shashkov, principal specialist for international cooperation for Roschimneft, western investors are welcome—there are no proscriptions on their holding shares in the corporation, although none so far has taken a stake.

Patricia Layman

New Puerto Rican plant points ICI's direction

Sir Denys H. Henderson, chairman and chief executive officer of the U.K.'s largest chemical company, ICI, was in Puerto Rico earlier this month to dedicate a new $60 million bulk pharmaceutical plant that will make atenolol, the active ingredient in Tenormin, the company's beta-blocker, used for the treatment of high blood pressure and heart disease.

That the ICI chairman would dedicate a small plant outside the U.K. says much about ICI's direction for the future. No longer strongly tied to its home country and to commodity chemicals, the British company is investing more and more overseas and is beefing up production of its higher value-added products, especially pharmaceuticals.

This is borne out by the shift in just where ICI's money comes from. As late as 1985, 27% of the company's sales and about 42% of its operating profits came from specialty chemicals, including drugs, pesticides, explosives, and other higher value-added products. In 1991, these product areas accounted for almost 67% of the company's sales and more than 80% of its operating profits. And the percentage of sales coming from the U.K. has declined to a little more than 20% in 1991 from about 27% in 1985.

This is in line with two of the four points of ICI's latest strategy—to increase higher value-added earnings and reduce exposure to commodity chemicals and to improve the company's worldwide spread. The other two points are to ensure that adequate funds are made available for research and development and to be internationally cost competitive.

Since July 1990, when the company annnounced it would restructure its operations, ICI has taken a number of steps to reduce its "exposure to commodity chemicals." It has significantly downsized its fibers operations, exited nearly all of its fertilizer businesses, and sold its soda ash business, for example. In total, the company has disposed of about $3 billion in assets over the past year and a half and through disposal and reorganization in the past year alone has reduced employment about 15,000 or 11%. During 1991, it sold more than 20 businesses and closed more than 20 production facilities.

However, during 1990 and 1991, ICI increased its investment in pharmaceuticals, explosives, acrylics, automotive finishes, and chlorofluorocarbon replacements.

The emphasis on value-added products at the expense of commodity chemicals does leave in question the fate of two of ICI's older and bigger businesses—fibers and plastics. Fibers have already gone through a downsizing and there is rumor in Europe that ICI would like to be out of the plastics business, since, as Henderson says, in general the businesses the company keeps "must be global winners"—a hard task for these two operations. But, he told C&EN, "we don't comment on rumors, so this must remain an area of conjecture."

William Storck

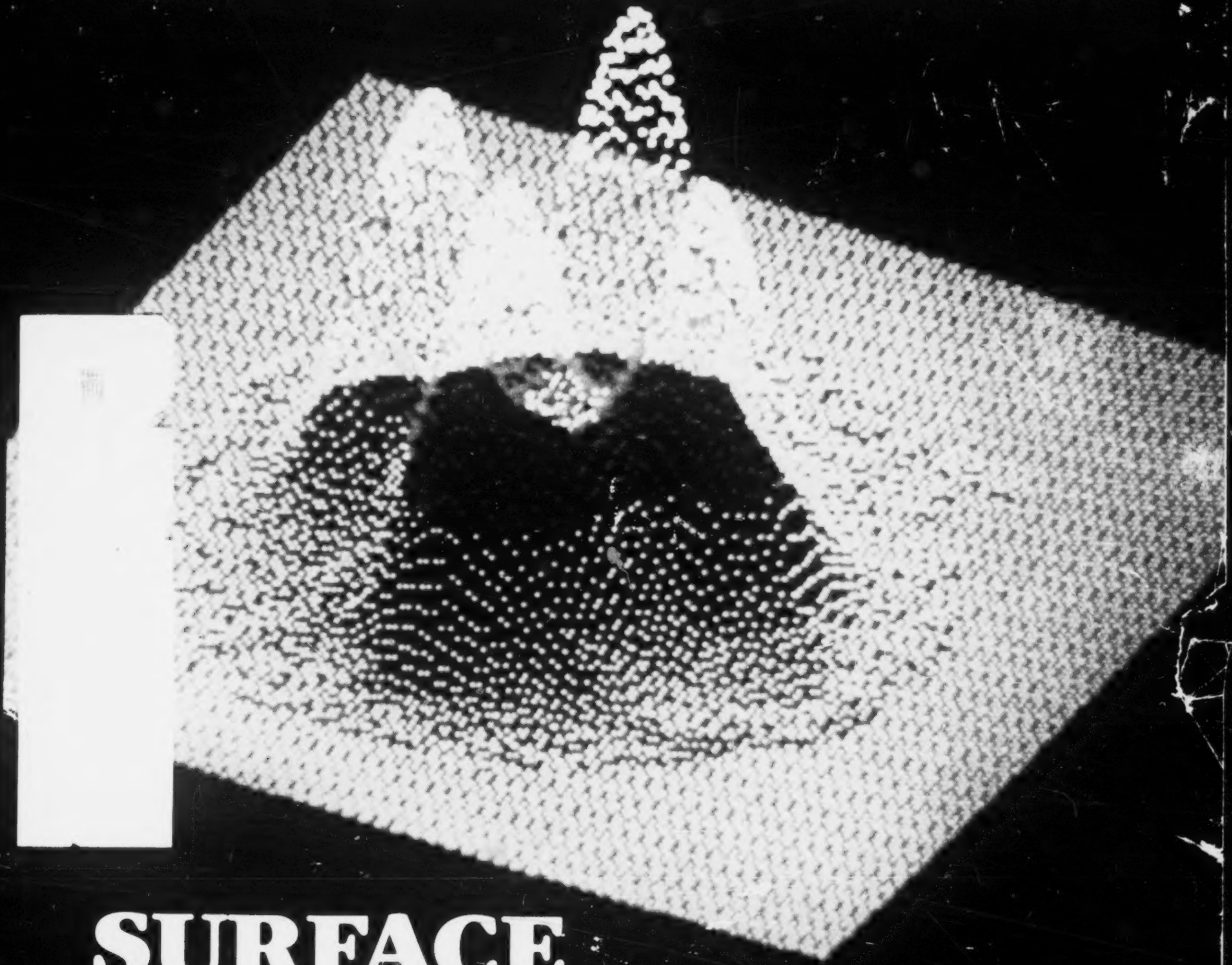
Rafael Hernández Colón, governor of Puerto Rico (left), and ICI's Henderson at plant dedication

CHEMICAL & ENGINEERING NEWS

C&EN

MARCH 30, 1992

BIOTECH FIRMS FINANCIALLY STRONG DESPITE LOSSES IN 1991 PAGE 9



SURFACE CHEMISTRY

Rich connections to technology Page 22

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NEWS OF THE WEEK

- Bolstering of federal support for precommercial R&D—the work occurring after basic research and before prototype creation—is urged in report issued last week. **Page 4**
- Australian effort to streamline text for global chemical weapons treaty is welcomed by participants in negotiations and may considerably shorten time for approval of final document. **Page 5**
- NIH director Bernadine Healy charges that leaks of confidential documents from the agency's scientific misconduct office endanger NIH. **Page 5**
- John Sheehan, organic chemist renowned for being the first to perform a total synthesis of a penicillin, dies at age 76. **Page 6**
- BASF Corp. agrees to sell its U.S. rayon fiber operations to Austria's Lenzing; firm also announces closing of plant in California. **Page 6**

COVER: Measurement of the chemical bond direction for adsorbed chlorine on the Si(100) surface produces this digital electron stimulated desorption ion angular distribution (ESDIAD) pattern. The image was generated by the Surface Science Center, Department of Chemistry, University of Pittsburgh.

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CENEAR 70 (13) 1-56
ISSN 0009-2347

BUSINESS

Biotech companies currently are flush with cash for R&D funding despite heavy losses in 1991 for many of them, primarily because of lucrative public stock offerings. **Page 9**

GOVERNMENT

House subcommittee criticizes as inadequate an EPA environmental equity report aimed at determining how the agency has responded to high environmental risks borne by the poor and minorities. **Page 13**

SCIENCE/TECHNOLOGY

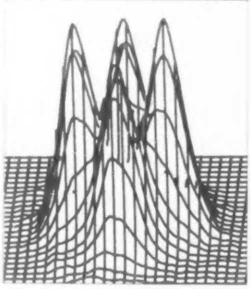
Amoco's new process for making polypropylene and ethylene/propylene copolymers features a unique reactor design and a high-activity catalyst. **Page 17**

Survey of U.S. undergraduate biochemistry departments by North Carolina State University shows that the University of California, Davis, is the largest, with 575 students. **Page 18**

ACS NEWS

ACS publications choose advisory board members; two new developments in ACS elections; society's News Service initiates series of news briefings for science journalists. **Page 19**

SPECIAL REPORT



The synergism of fundamental and applied research in surface chemistry has fueled a better understanding of the basic and applied activities of technologies such as heterogeneous catalysis, semiconductor processing, new materials development, and analytical techniques. Page 22

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600, TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr $105, 2 yr $189; outside U.S. 1 yr $141, 2 yr $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

Perfluorocarbon flammability

You have published a number of letters on perfluorocarbon flammability. All of these tried to correct possible misconceptions in the minds of the readers about perfluorocarbon inertness. The latest letter by Eric R. Larsen (C&EN, Feb. 17, page 2) gives a fine discussion on the elements necessary for flammability. His reference [Larsen's own publication, *Fluorine Chemistry Reviews*, **3**, 24 (1969)] is well worth reading for those interested in flammability of halogenated compounds. However, it would be incorrect to infer from Larsen's letter that the table of flammability limits includes many perfluorocarbons. In fact, there are only seven: two are the highly reactive aromatic compounds, perfluorotoluene and perfluorobenzene; three are cyclic compounds of lower stability than straight chain compounds; one is perfluorobutane, where the lower flammability limit in pure oxygen is given as "<50%"; and the last is hexafluoroethane, which does not have a lower flammability limit. Clearly, a generalization on the flammability of perfluorocarbons cannot be drawn from this group.

I believe there are three additional points to be made on this subject. First, the name perfluorocarbon, whatever the original intention was, has come to apply to organic compounds where the only element attached to carbon (other than another carbon) is fluorine. This means that the toluene with all the hydrogens replaced by fluorine is commonly called perfluorotoluene. This compound is a highly reactive compound because of the unsaturation in the ring, and it should be no surprise that it reacts violently with high-pressure oxygen (C&EN, Sept. 23, 1991, page 2). It would be wiser to restrict the perfluorocarbon name to fully saturated inert fluoro-organic compounds.

Second, the ultimate reaction of any organic compound with oxygen at extreme temperatures and pressures is also not surprising (C&EN, Oct. 7, 1991, page 2). In fact, neither oxygen nor other aggressive chemicals are needed at all for doomsday predictions with perfluorocarbons. Consider the following:

$$\underset{\text{Teflon}}{-(CF_2CF_2)_n-} \rightarrow nC + nCF_4$$

This reaction is exothermic to the extent of 29 kcal per mole, but, of course, the energy of activation is extremely high.

Third, a blanket assumption of inertness without examining all the data is unwise.

Louis L. Ferstandig
Vice President and Technical Director
Halocarbon Products Corp.
River Edge, N.J.

Undergraduate curricula

In Peter Lykos' letter (C&EN, Jan. 27, page 3), he has placed one of the central questions about undergraduate chemistry curricula on the table: What constitutes an introduction to our discipline, and why do we persist in offering up the cart before the horse in the form of general chemistry courses based on "baby p. chem."? Lykos suggests that a better representation of chemistry is the more qualitative model used by organic and inorganic chemists, which uses the language of chemistry and reasoning by analogy to describe observable, macroscopic changes in reactivity in terms of microscopic chemical structure. I am pleased to provide some observations from a curricular experiment based on exactly these principles, which began in September 1989 at the University of Michigan.

Last fall, using their performance on a 40-question ACS high school examination as a guide, 975 out of the 2500 students taking an introductory chemistry course at Michigan chose to start in a course titled, "Stucture and Reactivity." The two-term course uses mechanistic organic chemistry as the primary context for illustrating the how and why of scientific inquiry. Toward the end of their first year, it appears we are making a positive impact on the majority of these students, whether they were enrolled because of

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Biotech Companies In Good Shape Despite Large Losses in 1991

■ ***Stronger product sales, profits for several firms helped drive stock offerings to new highs, building cash reserves for many in 1992***

Ann M. Thayer,
C&EN Northeast News Bureau

Biotechnology companies have started 1992 with large bankrolls from which to fund R&D—despite large losses last year for many companies. This is because 1991 was the most prosperous financing year in the history of the biotechnology industry. Together, companies of every shape and size raised more than $4 billion through public stock offerings. Investors' overall enthusiasm for biotechnology—which includes a large number of young, unproven companies—was generated by the success of a handful of companies with big products and profits.

In addition, acquisitions of prominent biotechnology companies by large pharmaceutical firms, and by other biotechnology companies, placed tremendous market valuations on these companies despite their histories of problems. Chiron's merger with industry-pioneer Cetus was a major event within the industry for its sheer size at $650 million and the boldness of a successful, but only marginally profitable, Chiron. Since then, Cetus' key product, interleukin-2, finally received a favorable recommendation from a Food & Drug Administration advisory panel after long delays (C&EN, Jan. 27, page 6).

Genetics Institute, after a setback in a prolonged patent dispute with Amgen, sold a 60% interest to American Home Products for $660 million. Genetics Institute, which had reported sizable losses over the past few years, has gained a more comfortable cash position to support its promising, albeit long-term, R&D. In 1991, the company spent 82% of revenues on R&D. It does not expect to be profitable in 1992, since spending on R&D is to be increased significantly.

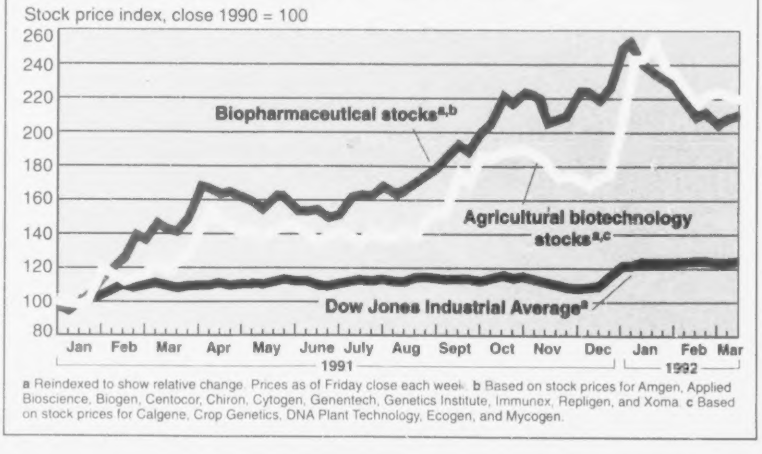
One of the biggest surprises for the industry came when Sandoz, the Swiss chemicals and pharmaceuticals producer, paid $392 million for a 60% stake in SyStemix. SyStemix, which is developing therapeutic agents based on immune and blood cell precursors, is only four years old and has no products in clinical trials. The company's stock, which became publicly traded only four months before the acquisition, rose to $54 per share and more than doubled SyStemix's market value.

Thus, throughout 1991, biotechnology stocks outperformed the stock market as a whole with the market valuation for biotechnology companies reaching more than $35 billion. The favorable environment for biotechnology stocks led to more than 85 public offerings in 1991, reports Feinstein Partners, a Cambridge, Mass.-based consulting firm. Of these, 35 were initial public offerings of stock. Among the standouts with initial offerings were Regeneron, which raised $99 million, and Affymax, with $92 million. Many others easily raised between $30 million and $60 million.

As stock prices continued to rise, at least 12 companies "double-dipped" into the market by following their initial public offering with a secondary stock offering. The results of secondary offerings were dramatic, with Synergen raising $225 million; Genzyme, $143 million; Chiron, $132 million; MedImmune, $109 million; and Immunex, $107 million. The performance of stocks after the offerings also was remarkable. Nearly 25 companies saw their stock values at least double, and others, such as MedImmune, saw prices triple or quadruple.

The stock market picture is not without its downside. Following Regeneron's initial public offering in April, its stock value crashed on critical analyst reports. In doing so, it contributed to a less positive outlook on biotechnology stocks overall. As investor interest cooled, the number of stock offerings dropped. This was typical of the continual ups and downs seen throughout the year, which can be attributed to the volatile and event-driven nature of biotechnology stocks.

Biotech stocks outrun stock market index



a Reindexed to show relative change. Prices as of Friday close each week. b Based on stock prices for Amgen, Applied Bioscience, Biogen, Centocor, Chiron, Cytogen, Genentech, Genetics Institute, Immunex, Repligen, and Xoma. c Based on stock prices for Calgene, Crop Genetics, DNA Plant Technology, Ecogen, and Mycogen.

However, by late summer and early fall, biotechnology stocks started climbing to a new high and the number of offerings grew once again. But this was followed by a November stock market downturn that hit biotechnology stocks harder than others. Several companies' stock prices, including those of big gainers MedImmune, Immune Response, and Synergen, fell as much as 15 to 20% overnight. Even successful, established companies such as Amgen, Biogen, and Chiron, saw stock prices drop 10%. Although stocks recovered and continued strong for the remainder of 1991 and in early 1992, they have since lost some of the earlier gains through market fluctuations and profit taking.

Those companies that took advantage of the stock market highs with successful stock offerings now have large amounts of cash with which to fund R&D. Companies such as Immune Response, Scios, ImmuLogic, Immunex, Regeneron, and Xoma list nearly $100 million or more in cash on their balance sheets; a host of others report as much as $50 million to $60 million. Despite a cost of $100 million or more to take a biopharmaceutical product from discovery through development, the money may sustain some companies, depending on their size, stage of development, and ability to manage the money wisely, for a few years. However, at the end of that time, many are expected to once again compete to raise capital.

More established companies, with products in later stages of development, spend a proportionately larger amount on R&D. Amgen spent $121 million on R&D in 1991, but has $378 million in cash as a result of its highly profitable business. Similarly, Genentech spent $221 million, or 43% of revenues, on R&D in 1991, but has $515 million in cash following its merger with Hoffmann-La Roche. Genentech and Immunex, which are both profitable, plan to increase expenditures to 50% of revenues in 1992. The industry average for R&D spending is about 63% of revenues, but can run as high as 200%, and is many more times that of the pharmaceutical industry average of 10 to 15%.

Chiron spent $79.4 million on R&D and, despite the cost of acquiring Cetus, has more than $300 million in cash. This comes in part from Cetus' sale of its polymerase chain reaction technology to Hoffmann-La Roche and the strength of Chiron's ophthalmics and

Biotech companies' losses outweigh profits in 1991

$ Thousands	Revenues[a]	Earnings	% change from 1990		Profit margin[b]	
			Revenues	Earnings	1991	1990
BIOPHARMACEUTICAL						
Affymax	$ 4,465	$ -8,605	312%	nm	def	def
Agouron Pharmaceuticals	4,922	-8,008	13	nm	def	def
Amgen	682,043	97,852	128	2432%	14%	1%
Biogen	69,577	7,186	17	-7	10	13
BioTechnology General	5,136	-7,930	19	nm	def	def
Cambridge Biotech	28,981	348	33	nm	1	def
Cambridge Neuroscience	1,085	-8,736	5	nm	def	def
Centocor	53,197	-195,555	18	nm	def	def
Chiron[c]	118,459	-425,131	51	nm	def	9
Cor Therapeutics	2,418	-5,116	405	nm	def	def
Cytel	7,109	-11,999	9	nm	def	def
Cytogen	10,851	-15,344	131	nm	def	def
Enzo Biochem	20,279	-8,242	-1	nm	def	def
Enzon[d]	4,058	-21,510	235	nm	def	def
Genelabs	4,261	-22,934	52	nm	def	def
Genentech	515,924	44,322	8	nm	9	def
Genetic Therapy	472	-4,824	167	nm	def	def
Genetics Institute	82,551	-10,748	105	nm	def	def
Genzyme	121,706	18,881	122	nm	16	def
ImClone	800	-7,599	-84	nm	def	def
ImmuLogic	4,604	-9,941	-2	nm	def	def
Immune Response	4,253	-3,001	-1	nm	def	def
Immunex	62,615	802	80	nm	1	def
Immunogen	2,137	-12,648	-32	nm	def	def
Immunomedics	8,057	542	83	nm	7	def
Isis Pharmaceuticals	8,043	-8,737	311	nm	def	def
Liposome	8,832	-4,086	25	nm	def	def
MedImmune	13,952	1,624	327	nm	12	def
MGi Pharma	8,657	-8,715	36	nm	def	def
NeoRx	315	-11,651	-82	nm	def	def
Nova Pharmaceuticals	50,094	-14,852	39	nm	def	def
Oncogene Science	8,334	-2,305	36	nm	def	def
Regeneron	12,508	-4,468	149	nm	def	def
Repligen	9,637	-13,426	-10	nm	def	def
Ribi ImmunoChem	1,386	-3,217	5	nm	def	def
Scios[e]	7,357	-17,251	-41	nm	def	def
Synergen	23,822	-7,120	87	nm	def	def
T Cell Sciences	10,548	-4,093	-12	nm	def	def
Xoma	17,140	-34,342	16	nm	def	def
AGRICULTURAL						
Calgene[f]	8,001	-8,783	0	nm	def	def
Crop Genetics	3,344	-8,386	13	nm	def	def
DNA Plant Technology	10,902	-14,941	19	nm	def	def
Ecogen	6,940	-10,529	217	nm	def	def
Mycogen	23,642	-3,305	58	nm	def	def
OTHER						
Applied Bioscience	113,779	12,473	14	53	11	8
Collagen	62,617	-7,852	7	nm	def	6
Immucor	25,079	3,431	68	37	14	17

a Includes product sales, contract research, royalty, and interest revenues for calendar year. **b** After-tax income as percentage of sales. **c** Acquired Cetus in December 1991. Loss includes one-time charge of $426 million. **d** Acquired Genex in June 1991. **e** Name changed in early 1992; previously known as California Biotechnology. **f** Results reported for second half of 1991 only because of change in fiscal year. **def** = deficit. **nm** = not meaningful.

Companies' major products rack up huge sales

Company	Products	1991 sales ($ million)	% change from 1990
Amgen	Erythropoietin and granulocyte colony-stimulating factor	$645.3	129%
Biogen	α-, β-, and γ-interferons; hepatitis B vaccines and diagnostics	56.5[a]	26
Centocor	Antisepsis monoclonal antibody; cancer diagnostics	44.3[b]	35
Chiron	Diagnostics and ophthalmics	28.2[c]	91
Genentech[d]	Human growth hormone	185.1	18
	Tissue plasminogen activator	196.5	–6
	γ-interferon	1.5	nm
Genetics Institute	Erythropoietin	18.4[e]	124
Genzyme	Glucocerebrosidase	81.1	134
Immunex	Granulocyte macrophage colony stimulating factor	34.2	601

a Predominantly royalty income from sales by licensees. Actual sales estimated to be several hundred million dollars. **b** European sales. **c** Does not include revenues from sales by joint businesses. **d** Does not include royalty income from licensees' sales of human insulin and α-interferon. **e** Royalty income on sales by European and Japanese partners. **nm** = not meaningful.

diagnostics businesses. Similarly, based on the strength of its royalty income from products it has developed and a $74 million stock offering, Biogen has the cash to back its more than $40 million R&D program.

Although large companies spend more, they are more likely to have other sources of revenue and thus their survival rates are slightly higher than for small companies. Most biotechnology company revenue comes not from earnings, but rather from collaborative R&D arrangements, interest income, and private investments. But for companies with products, such as Amgen, Genentech, Genzyme, and Immunex, sales of a major product can be substantial.

Combined sales of these companies' products—seven of the 14 approved to date by FDA—totaled more than $1.1 billion in 1991. Amgen's red blood cell stimulant, erythropoietin, became the top-selling product for a biotechnology company. Amgen's revenues of $682 million and a net income of $97.9 million made it the leading biotechnology company. Genentech's human growth hormone showed increased sales, but its tissue plasminogen activator lost ground because of strong competition from less expensive drugs. Net income for the company was $44.3 million on revenues of $516 million.

Colony-stimulating factors are just beginning to show their potential, having first been approved in 1991, and have contributed to product sales for Immunex and Amgen. Biogen's $57 million in royalties, meanwhile, are only a small reflection of the magnitude of licensees' sales of α-interferon and hepatitis B vaccines and diagnostics. And, at $81 million in sales in just about eight months on the market, Genzyme's enzyme therapeutic product, Ceredase, contributed to two thirds of that company's $122 million in revenue. Genzyme had a net income of $18.9 million in 1991.

Speculation that products might soon emerge from among the 100-plus biotechnology drugs in clinical trials and more than 20 awaiting FDA approval keeps the excitement level high. Monoclonal-antibody-based therapeutics and imaging agents, blood clotting factors, and interleukin-2 are anticipated to be the next products to receive marketing approval. Expanded uses for approved products such as the colony-stimulating factor and interferons also are expected to get marketing okay. Still, only a handful of biotechnology companies are profitable and more companies continued to lose money than make it in 1991.

The biggest losses were reported by companies that had been investing heavily in R&D, product development, and setting up manufacturing and marketing efforts. Chiron's acquisition of Cetus cost the company a $426 million charge against earnings in 1991 for a net loss of $425 million after having reported a profit in 1990. In 1991, the company had revenues of $118 million and anticipates returning to profitability in 1993.

Centocor reported a $196 million loss on revenues of $53 million for 1991. The loss was due in part to a $70 million charge for acquired research. The company has been expanding its sales and marketing efforts in Europe where its monoclonal antibody product, Centoxin, has been approved for treating sepsis. The company is involved in fierce competition and patent disputes with Xoma, although both companies' products have faced delays at FDA.

A side of the industry that has generated less excitement is agricultural biotechnology. Even so, this area of development also is showing gradual progress and growth by the companies involved. Although none of the five companies followed in the C&EN agricultural biotechnology stock index—Calgene, Crop Genetics, DNA Plant Technology, Ecogen, and Mycogen—reported a profit for 1991, they have strengthened their financial and product development positions.

In 1991, EPA approved the first two genetically engineered biopesticides developed by Mycogen for commercial sale. Although product sales are still low and money was spent on acquiring new technology, the company has managed to increase its cash balance to about $76 million through a stock offering.

Calgene refocused its business last year and anticipates commercial developments for its genetically engineered crops. DNA Plant Technology is using proceeds from its October 1991 offering to expand development of its core businesses. For Crop Genetics, a major event in 1991 was the signing of its first large collaborative agreement with Du Pont.

In 1991, Ecogen saw revenues more than triple over 1990. New alliances, new technology, and increased assets contributed to a major comeback in the value of the company's stock, increasing fivefold over the start of 1991 and remaining strong in 1992.

Whereas the excitement toward biotechnology permeated the entire industry in 1991, most observers do not expect this to continue and anticipate that high-priced biotechnology stocks are susceptible to a fall. A major uncertainty hanging over individual companies' success is the lengthy, expensive, and uncertain product development and regulatory approval processes. Unless more than the handful of biotechnology companies showing profits can deliver high-quality science, real products, and profits, the opportunity for raising capital will fade. □

Because very little combustible liquid material is in the reactor at any time, the gas-phase processes are inherently safer than other types. Slurry processes, for example, involve great volumes of solvents.

Moreover, the gas-phase processes, because they do not require steam or solvents, involve only polymerization and pelleting equipment. This simpler approach can reduce construction costs up to 30% over conventional slurry processes of similar capacity, Brockmeier says. Operating costs also are lower, he says, as much as 35% less than for slurry processes, excluding monomer costs.

The major differences between the three major gas-phase processes involve heat removal and agitation. The BASF/ICI/Norchem and Amoco/Chisso processes use mechanical agitation, whereas the Union Carbide/Shell process uses a fluid bed, which is also an efficient remover. The BASF/ICI/Norchem and Amoco/Chisso processes depend on the latent heat of vaporization of propylene as a heat sink.

The Amoco/Chisso process consists of several major steps. First is monomer purification. Monomers must be very pure, with such catalyst poisons as moisture, sulfur compounds, and oxygen reduced to concentrations of less than 1 ppm. The simplest part of the process, according to Brockmeier, is handling the catalyst: catalyst, cocatalyst, and modifiers are fed to the reactor, through appropriate meters, directly from the shipping containers.

The distinctive feature of the Amoco/Chisso process is the reactor, Brockmeier says. Catalyst is injected at one end of the reactor, and product is removed from the other end. The residence time distribution in the reactor resembles that of plug-flow in a tubular reactor. This allows quick transitions from one product grade to another as well as between homopolymers and copolymers. Process shutdowns from fouling are not required, he says, and startup is easy, even if the reactor has been exposed to the atmosphere.

The heat of polymerization is removed by vaporizing condensed recycle monomer that is sprayed on the stirred powder bed. The evaporated monomer leaving the reactor is partially condensed and recirculated for cooling. Makeup monomer is added to the recycle as needed.

In homopolymer production, propylene is the only monomer fed to the system. For random copolymer production, a controlled amount of ethylene is added. Impact copolymer production requires addition of a second reactor, similar to the first, with a gas lock between them.

The reactor/catalyst system is stable enough for the process to be stopped simply by halting flow of the catalyst to the reactor, Brockmeier says. In an emergency, the process can be shut down within three minutes by venting pressure to the flare system. It can be restarted by repressurizing the system back to the operating pressure.

The powdered product from the final reactor is periodically discharged into a separation system, where excess monomer is removed for recycling and a countercurrent gas stream deactivates the catalyst. The deactivated product is then mixed with stabilizers. Pelleting is done with water. After dewatering, the product is sent to storage. Except for the product itself and a small gas stream that is flared to the atmosphere, no effluents result from the process.

The demand for polyethylene and polypropylene products continues to grow. It's estimated that world demand will grow 5% per year through the 1990s and that world production of these products will be about 10 million tons per year in the near future. The most promising locations for expanding production in polyethylene/polypropylene products at present are Southeast Asia, the Middle East, and Latin America. The developed countries will continue to expand production at a slower rate.

Joseph Haggin

Size of U.S. biochemistry departments surveyed

The University of California, Davis, has the largest undergraduate department of biochemistry in the U.S., with 575 undergraduates, according to a survey conducted last year by the biochemistry department at North Carolina State University, Raleigh. The survey covers 1990 data from departments at 98 universities.

Paul F. Agris, head of NC State's department of biochemistry, says he's not aware of any other survey of the size of undergraduate biochemistry degree programs in at least a decade. NC State, which ranked second in the survey, had 245 undergraduates in 1990. However, the department has been growing fantastically, Agris says, and now has more than 320 majors and comajors. Many of the students, he points out, double major in either chemistry or chemical engineering. A survey of NC State graduates, he adds, has shown that about 50% enter graduate schools. Of the other 50%, most find jobs in technical fields in industry or academic and medical institutions, with a few going into sales.

Among the data gathered in the survey were level of degrees in biochemistry, number of faculty members, number of students majoring in biochemistry, number of foreign versus U.S. students, and course information such as size of lecture classes, number of staff in the department, and some budgetary information. In reporting data for comparison, the survey sponsors averaged data for most categories and selected certain institutions to represent the three subgroups of public, private, and public southeastern institutions.

James Krieger

Of undergraduate biochemistry programs, UC-Davis is largest

University	Number of undergraduates	Number of biochemistry faculty[a]
University of California, Davis	575	18
North Carolina State University	245	12
Virginia Polytechnic Institute & State University	240	20
University of Wisconsin, Madison	217	29
Northwestern University	200	32
University of California, Riverside	185	15
Michigan State University	174	36
University of Arizona, Tucson	168	48
University of Missouri, Columbia	150	30
Pennsylvania State University	119	27

Note: Data are for 1990. **a** Full-time equivalent faculty. **Source:** North Carolina State University survey of biochemistry degree programs in the U.S., 1990–1991.

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COVER: U.S. Customs officers inspect chemical shipment at Houston dock. Photo by Billy L. Mason, U.S. Customs Service

Volume 70, Number 14
CENEAR 70 (14) 1–66
ISSN 0009-2347

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Committee on Professional Relations is concerned that its mass termination reports are understating the seriousness of unemployment among chemists, particularly older ones. **Page 44**

NEWS FOCUS

U.S. chemical industry strongly backs a North American Free Trade Agreement, but with some caveats: basically, the most liberal trade and investment conditions possible. Page 7

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
Robert H. Marks, Director, Publications Division

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman*: Joseph A. Dixon; *President*: Ernest L. Eliel; Richard L. Deming; Judith C. Giordan; William P. Jencks; and Gary J. Long

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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
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LETTERS

Survey of chemists

The following letter from International Union of Pure & Applied Chemistry president Allen J. Bard invites chemists to offer their advice and recommendations on projects that might be addressed within IUPAC programs.

Dear chemist: Each year the various commissions and committees of IUPAC undertake many projects. In general, these projects are related to the needs of world chemists and the role of chemistry in meeting the needs of humankind. These often deal with problems of nomenclature, symbols, terminology, and conventions. They also include critically evaluated data compilations, recommended measurement procedures and analytical methods, recommended standards, and guidelines for publication.

Although the various bodies of IUPAC contain chemists who are very knowledgeable in their specialties, it is clearly not possible to cover the full breadth of chemistry within the limited membership of the union. Thus, there may be important problems and projects suitable for IUPAC study that are not undertaken in a timely manner. We are therefore soliciting the chemistry community through chemistry journals and magazines for advice and recommendations on projects that might be addressed within IUPAC programs. If you know of such projects, please send a suggested project title, a brief description of the nature of the problem, and the names and addresses of suggested experts in the project area to Michael Freemantle, IUPAC Secretariat, Bank Court Chambers, 2-3 Pound Way, Templars Square, Cowley, Oxford OX4 3YF, U.K. Thank you for your advice and interest.

Allen J. Bard

Reversing the ban on EBDCs

A brief news item (C&EN, Feb. 24, page 6) indicates that the Environmental Protection Agency now permits the sale of ethylenebis(dithiocarbamates), or EBDCs, an important class of agricultural chemicals. To some, EBDCs were suspect because, as used, they release a small amount of ethylene thiourea (ETU).

We were the first to report that chronic administration of 350 ppm ETU in the diet of male and female rats induced goiter in the thyroid (hyperplasia) and thyroid carcinoma [*J. Natl. Cancer Inst.*, **49**, 583 (1972)]. A much lower yield of cancer of the thyroid was obtained with 175 ppm ETU. ETU and other thioureas act as goitrogens, leading to thyroid-pituitary hormone imbalances. Thus, the carcinogenic effect is due to such imbalances, accounting for the steep drop in effect with only a 50% lower dose.

Trace amounts of ETU, a nongenotoxic agent, insufficient to affect hormone balances, would not be expected to cause cancer. No case of thyroid cancer was found in workers in the rubber industry with probable exposure to a higher amount of ETU than would be derived from EBDCs [*IARC Monogr. Supp.*, **7**, 207 (1987)]. The high-level ETU in rats is effective because it acts as a goitrogen. Certain vegetables, like cabbage, also contain goitrogens, without obvious harm in populations with an adequate dietary iodide intake. Thus, the initial ban of EBDCs failed to take into account the mechanism of action of ETU. The staff of EPA needs to be congratulated that they have now taken the proper action, based on the relevant mechanism.

John H. Weisburger
American Health Foundation
Valhalla, N.Y.

Perfluorocarbon flammability

I would like to comment on the letter by Eric Larsen (C&EN, Feb. 17, page 3) in which the topic of perfluorocarbon flammability is discussed. The general subject of material flammability in oxygen has been presented in numerous papers at symposia sponsored by the American Society for Testing & Materials G.04 committee, which is concerned with flammability and sensitivity of materials in oxygen-enriched environments.

An issue with the polymer polytetrafluoroethylene (PTFE) is that it contains no appreciable volatiles as a result of the high number average molecular weight, which is typically 10^6 g per mole or more. It has a melting point, typically, of 327 °C and degradation products (measured with TGA and FTIR in oxygen) are detectable at approximately 400 °C and above (CO_2, CO, COF_2, and CF_4) [Tapphorn, R.M., Shelley, R., Benz, F., "Test Developments for Polymers in Oxygen-Enriched Environments," in "Flammability and Sensitivity of Materials in

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U.S. Chemical Industry Supports North American Free Trade Pact

With its focus on Mexico, industry wants the most liberal trade and investment rules possible; particular goal is strong agreement on petrochemicals

Earl V. Anderson, C&EN Northeast News Bureau

Negotiators struggling with the many complex and difficult issues involved in fashioning a North American Free Trade Agreement (NAFTA) may or may not finish their job by the middle of the month as hoped.

An agreement, linking Canada, Mexico, and the U.S. in a massive free trade area may or may not reach Congress this year —an election year in which trade has emerged as an important political issue. And when, or if, the agreement does reach Congress, it may or may not generate enough support to win approval.

Speculation and conjecture are rampant. There are no sure bets—one way or the other. What is certain, however, is that the chemical industries in all three countries have a lot riding on the outcome of the negotiations.

In previous issues, NAFTA was examined from the Mexican chemical industry point of view (C&EN, Sept. 9, 1991, page 7) and from the Canadian perspective (C&EN, Jan. 27, page 9). This final article of the series presents the U.S. chemical industry position on NAFTA.

The regional trade bloc bound by NAFTA, stretching from the Yukon to the Yucatan, would be one of the biggest and richest markets in the world—a single bloc with a $6 trillion annual output encompassing 360 million consumers.

For a globally oriented industry such as the U.S. chemical industry, that is reason enough to command attention. And there is no doubt that the industry is paying very close attention to developments in the NAFTA negotiations. Like its counterparts in Canada and Mexico, it has a lot riding on the outcome.

Last year, total chemical trade among the three countries was almost $14.5 billion. All but a pittance involved U.S. chemical exports or imports. U.S. chemical exports to Canada and Mexico last year hit $9.3 billion, almost 22% of all the chemicals it exported. The U.S. imported more than $5 billion in chemicals from the two countries, which is about 21% of total chemical imports.

Canada, in fact, is the U.S.'s largest chemical export market. Mexico is the third largest. And the U.S. imports more chemicals from Canada than any other country, with Mexico ranking a respectable seventh. Just as important, chemical exports to both Canada and Mexico have grown faster than total chemical exports over the past few years.

Since 1988, for instance, U.S. chemical exports to Canada have increased an average 16% per year, and to Mexico, 13%, whereas total chemical exports have grown an average 11%. And although growth of chemical imports from Canada has trailed the average, imports from Mexico have been growing more rapidly.

Little wonder, then, that the U.S. chemical industry has a vested interest in the NAFTA negotiations. And it's probably safe to say that U.S. chemical companies are more preoccupied with what Mexican negotiators bring to the bargaining table than with what the Canadians bring.

This is no slight on Canada. Far from it. U.S. chemical industry trade with and investment in Canada dwarfs its business with Mexico. It's just that for the past three years the U.S. and Canada have had a free trade agreement.

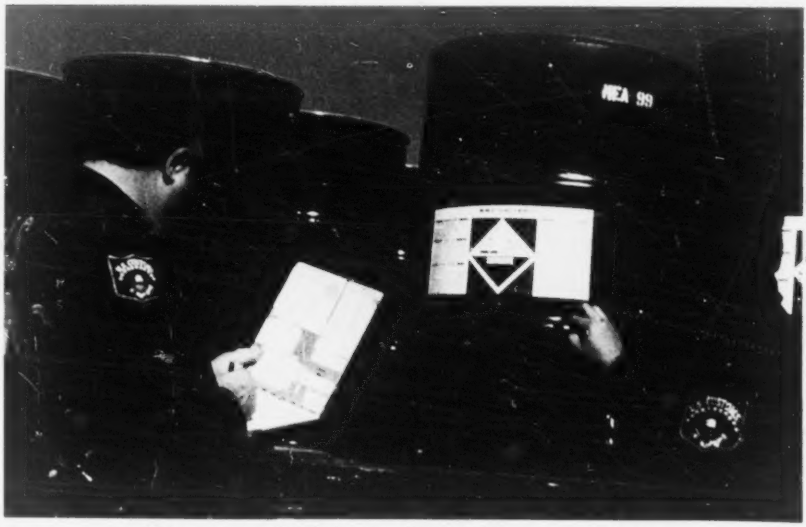
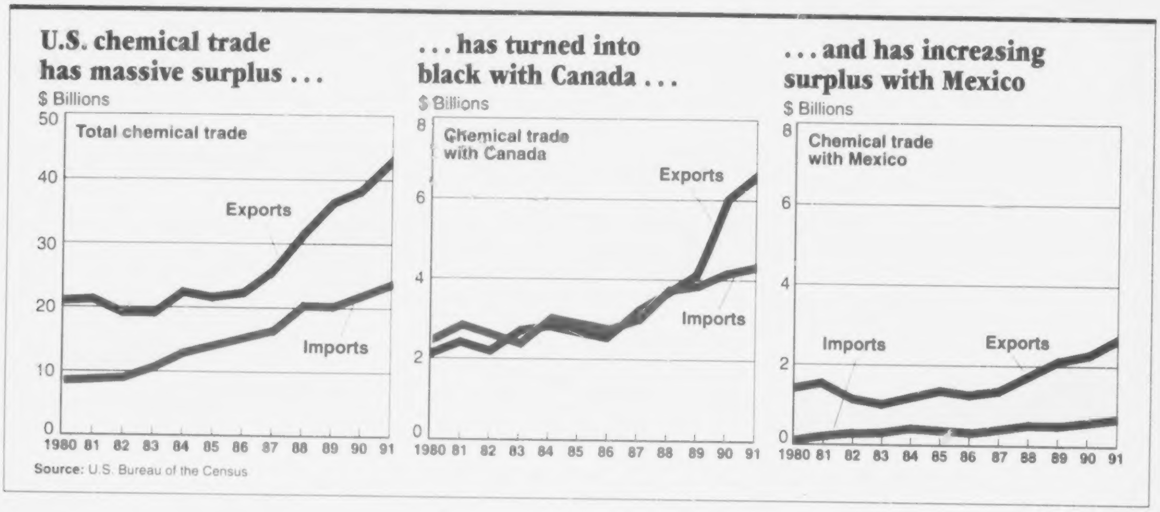


Photo by Bill Mason, U.S. Customs Service

U.S. customs officials inspect chemical drums at port of entry



U.S. chemical trade has massive surplus . . .

. . . has turned into black with Canada . . .

. . . and has increasing surplus with Mexico

Source: U.S. Bureau of the Census

The U.S. chemical industry believes the current agreement has some shortcomings. The industry would like to see some parts improved, and it would like to see some things added in the NAFTA negotiations, if possible. And certainly it doesn't want to see NAFTA weaken the present free trade agreement in any way.

But the industry has supported the Canada-U.S. trade agreement and generally has benefited from it. Since it became effective Jan. 1, 1989, U.S. chemical exports to Canada have increased 78%.

From its very conception, the industry also has been a strong supporter of NAFTA. But, as with the current trade agreement, that support doesn't come without some caveats.

For most of the U.S. chemical industry, those caveats are contained in a policy statement that the Chemical Manufacturers Association (CMA) issued last June. It outlines CMA's positions on most of the issues that are important to the chemical industry. Among them: petrochemicals and petrochemical feedstocks, investment, tariffs and nontariff barriers (together called market access), intellectual property rights, and rules of origin. Some of these were dubbed sticky issues when the negotiations began. And they remain sticky issues in the NAFTA negotiations.

The bottom line: Nail down the most liberal trade and investment conditions possible. But CMA's policy statement doesn't cast the industry in cement. K. James O'Connor Jr., CMA's associate director of international trade, notes the statement features the word "should," not "must." And certainly not every U.S. chemical company agrees with every dotted *i* and crossed *t*. Nevertheless, the CMA policy statement pretty well defines what the U.S. chemical industry wants to see emerge from the negotiations.

What it wants to see emerge as much as anything is a strong agreement on petrochemicals. Even before the negotiations began, petrochemicals surfaced as a sensitive political issue. It still is.

The reason is Mexico's constitution, which reserves dealing in oil, natural gas, and some petrochemicals exclusively for Petróleos Mexicanos (Pemex), the state-owned energy and petrochemical monopoly. This effectively divides that country's petrochemical industry into two sectors—public and private.

The public sector, incarnate in Pemex, oversees production of those petrochemicals on a list of "primary," or basic, petrochemicals. Over the years, that list has been pared considerably. Many products that once were classified as primary have been reclassified. In 1986, Mexico erased 36 products from its primary list. In 1989, it cut the primary list further, from 67 to only 20 products. Since then, methyl *tert*-butyl ether, the increasingly popular gasoline additive, has been taken off. The list now contains 19 key petrochemicals. These products are off-limits to private companies—domestic or foreign.

The private sector can produce all other petrochemicals. However, Mexico has another list of 66 "secondary" petrochemicals on which foreign direct investment is restricted to 40%. Foreign investment is unrestricted for petrochemicals that do not appear on either list.

The U.S. chemical industry's concerns about petrochemicals are twofold: petrochemical investment and access to petrochemical feedstock and raw materials in Mexico. The two are closely interrelated. U.S. chemical companies interested in producing in Mexico want assured access to petrochemical feedstock. They want to be able to produce in Mexico petrochemicals that the law now does not allow. And they want no restrictions on their ability to invest anywhere along the petrochemical chain.

The reasons are obvious: the more secure the supply of feedstock, the better. In addition, most large-scale petrochemical operations are more profitable when they are vertically integrated. Any break in the integration chain eats into profitability. And, although its record is improving, Pemex has earned a reputation as an unreliable supplier of petrochemicals to its downstream customers.

However, the oil, natural gas, and petrochemicals that the Mexican constitution reserves for Pemex are an emotional national symbol for most Mexicans. Ever since Lázaro Cárdenas, one of Mexico's most revered presidents, nationalized the oil industry in 1938, Mexicans have regarded their right to sole ownership as a matter of faith.

In Mexico, to tamper with these constitutional provisions is like walking on political eggs. In the U.S., although there are some who say that these provisions are open to interpretation, most chemical executives involved in the NAFTA negotiations say that they are well aware of and respect Mexico's sensitivity on the issue.

Nevertheless, CMA's policy statement says a NAFTA based on a "free market system" will bring the greatest benefits to both Mexican and U.S. chemical companies. It says private companies, both Mexican and foreign, should be provided access to crude oil, natural gas, and other natural resources. It also says production restrictions on primary and secondary petrochemicals should be eliminated. And, according to the policy statement, preferential fees or taxes on chemical raw materials should gradually be reduced to zero.

The operative word is "should." Says CMA's O'Connor: "You have to be flexible in any negotiation. If we paint ourselves into a corner on any single issue, then we're forced to reject the agreement if it doesn't meet our demands, even if the total package is beneficial." You can't be rigid and come out a winner, he adds.

Some U.S. chemical companies may have their own "wish lists" of petrochemicals that they would like to see opened up to foreign investment and production in Mexico. Each of their lists is geared to what they see as niche opportunities. But, to remain flexible, the chemical industry's private-sector advisers to U.S. trade officials haven't developed a firm position on just how much of Mexico's lists of restricted petrochemicals should be eliminated. One adviser, not speaking for attribution, asks what is gained if all the petrochemicals are decontrolled and Pemex still retains sole control of oil, natural gas, and naphtha? His answer: not very much.

However, O'Connor thinks there's not much sense in demanding that Pemex be privatized. It's one thing for the U.S. and Canada to present Mexico with a package of "what we see as goals." It's another, he adds, to tell Mexico how to do it and how far to go.

In effect, the pivotal issue on petrochemicals may not be so much one of ownership, but of access—secure, reliable, and sufficient access to feedstocks at nondiscriminatory, world market prices. Indications are that, if U.S. negotiators could get that secured access to feedstocks and a significant reduction in the restricted petrochemical lists, the U.S. chemical industry could live with it.

Fernando Arozena, a trade attorney for Dow Chemical who also chairs CMA's NAFTA task force, says Dow doesn't want to make it a big issue. "We recognize and appreciate the peculiarities and restrictions of the Mexican system, but don't regard them as a major concern."

Of course, the Mexican chemical industry and Mexican negotiators have their own ideas about the petrochemical sector negotiations. And because no agreement is in sight yet for the sector indicates that Mexico and the U.S. are still at odds on this issue. As one chemical trade adviser puts it, "The main lightning rod for our industry hasn't even been drafted yet."

Larry Gess, marketing manager at Nalco Chemical who also is on the staff of the Office of the Chemical Industry Trade Adviser (OCITA), says there has to be an intersection along the petrochemical chain somewhere. "But frankly," he says, "I don't know where that intersection is going to come."

One chemical expert close to the negotiations believes the petrochemical issue could be solved easily. All it would take is for Mexico to allow the private sector, including foreign companies, to produce petrochemicals, starting with ethylene and propylene, and continuing down the petrochemical chain. That would satisfy the big U.S. petrochemical producers, help the Mexican chemical industry at the same time, and send a signal to the others that Mexico is serious about an open-market system.

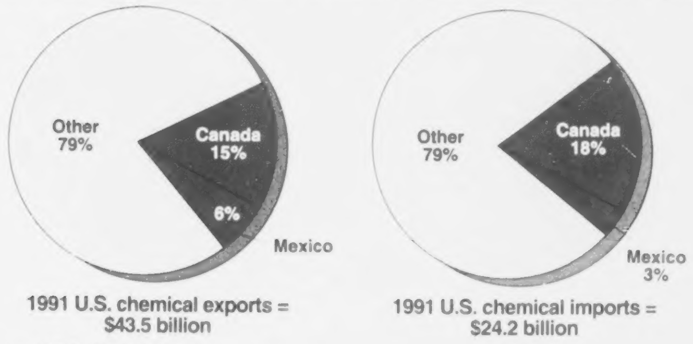
This petrochemical issue is a two-headed creature. Although it is being negotiated in the energy group, petrochemicals also spill over into the NAFTA group handling investments. That's because Mexico prohibits private investment of any kind on those 19 primary petrochemicals reserved for Pemex.

There are some in the U.S. chemical industry who say that if those restrictions are slimmed down to their satisfaction, the entire investment issue would automatically be resolved to their satisfaction as well. Others say that it is not quite that simple.

For instance, Mexico limits foreign investment for the 66 petrochemicals on the secondary petrochemical list to a maximum of 40%. And, although U.S. companies can actually own more than the legal 40% through a financial sleight of hand known as investment trusts, most U.S. chemical trade advisers would prefer to see an end to all restrictions that limit or prohibit full foreign ownership in Mexico. That's what CMA's policy statement also calls for.

CMA also wants the same rights and protection as Mexican investors, both private and public. In other words, "national treatment." There should be no minimum domestic content requirements or export performance requirements placed on for-

U.S. chemical trade more with Canada than with Mexico



Source: U.S. Bureau of the Census

eign investment. And U.S. chemical companies should have an unrestricted right to repatriate capital and remit profits. With 1938 still clear in its memory, CMA also has established guidelines for expropriation. Chief among them is that expropriations not only be limited to standards of international law, but also include that they be only for public purposes, nondiscriminatory, and accompanied by payment or prompt and adequate compensation at fair market value determined by international arbitration.

U.S. chemical industry trade experts unanimously give Mexico high marks for the progress it has made in opening its economic doors to foreign investment. However, they do have some reservations. For instance, the underlying law governing foreign investment in Mexico remains unchanged. Instead, Mexico liberalized foreign investment through decrees and regulations. More than a few in the U.S. chemical industry fear that a different administration in Mexico could interpret the law differently and change the existing regulations.

"In a nutshell," says one industry trade expert, "we want Mexican investment laws to be as close as possible to U.S. investment laws." Yet, there are some in the chemical industry who think that the investment issue is being blown out of proportion. They say that seeking completely unrestricted chemical investment in Mexico is like jousting with windmills. All too often, they point out, foreign operations of U.S. companies are much more successful when they are joint ventures with local partners.

Whatever investments Dow may make in Mexico, says Arozena, will not depend on the shape of the investment agreement that comes out of NAFTA. They will depend, instead, much more on market conditions.

The investment issue is another example of putting the focus on Mexico in the NAFTA negotiations. But in the real world, the action is in Canada. The book value of U.S. direct investments in Canada's chemical industry was $6.4 billion at the end of 1990. In Mexico, it was much less—only $1.6 billion.

In any trade negotiation, tariffs rank high on the list of concerns for the U.S. chemical industry. The NAFTA negotiations are no exception. And for these negotiations, the industry thinks that the U.S.-Canada free trade agreement can serve as an excellent guide.

The industry believes that NAFTA should make it possible for the three countries to eliminate tariffs on chemicals in one of three ways: immediately, in stages over a period no greater than five years, or over a longer period of time for import-sensitive items. That's how it's done under the U.S.-Canada trade agreement and how the U.S. chemical industry proposes it be done in the Uruguay round of multilateral trade negotiations in Geneva, sponsored by the General Agreement on Tariffs & Trade (GATT).

The current trade agreement also makes it possible to accelerate staged-tariff cuts. And CMA believes NAFTA should do the same, as long as no producer in any of the three countries objects. There's some dissatisfaction with the current trade agreement on this score, because one inconsequential producer can block an accelerated tariff cut that all of the major producers want. U.S. chemical producers want to see this corrected in the NAFTA tariff negotiations. To do this, the tariff agreement should establish specific criteria for raising objections to accelerated tariff cuts.

U.S. is chemical-producing heavyweight of the three countries

Thousands of metric tons	1990 production				
	U.S.	Canada	% of U.S.	Mexico	% of U.S.
Sulfuric acid	40,171	3311	8.2%	3974	9.9%
Ethylene	17,001	2425	14.3	1370	8.1
Ammonia	15,386	3602	23.4	2632	17.1
Sodium hydroxide	10,605	1651	15.6	429	4.0
Propylene	10,037	766	7.6	366	3.6
Chlorine	9,925	1542	15.5	387	3.9
Benzene	5,380	765	14.2	320	5.9
Methanol	3,624	1884	52.0	210	5.8
Toluene	2,767	427	15.4	368	13.3
Xylene	2,586	514	19.9	404	15.6
Butadiene	1,433	192	13.4	21	1.5
Carbon black	1,302	178	13.7	125	9.6
Polyethylene, low density	5,071	1167	23.0	348	6.9
Polyethylene, high density	3,778	364	9.6	176	4.7
Polystyrene	2,273	215	9.5	130	5.7

Sources: U.S. Bureau of the Census, U.S. International Trade Commission, Statistics Canada, Asociación Nacional de la Industria Química

One key element of the industry's position is that for petrochemicals, the staging time—that is, the length of time it takes to completely eliminate tariffs—should be the same for all three countries. "Symmetrical staging," O'Connor calls it. The reasoning is that, because the petrochemical industries in all three countries have a similar level of technical sophistication, the staging time to eliminate tariffs should be the same.

It's a position that doesn't sit well with the Mexican chemical industry. It believes that, because Mexico's level of economic development lags that of the U.S. by a wide margin, it should receive longer staging periods. This would allow Mexico time to adjust to the new stiff breeze of competition. On this, "we (the Mexican and U.S. chemical industries) agree to disagree," says O'Connor. Nor has this issue been settled yet in the NAFTA negotiations.

The chemical industry, through CMA, has told U.S. negotiators that the tariff agreement also should include a deadline for compliance and specific penalties if one country fails to comply with the agreement "on a continuing basis." If that were the case, says CMA, the injured party should be able to reimpose its "most-favored-nation" tariff rates.

After joining GATT in 1986, Mexico reduced many of its tariffs and "bound" them so that they cannot be raised. Since then, it has reduced tariffs even further, but these lower "applied" rates are not bound. Naturally, the U.S. chemical industry wants these lower Mexican applied rates to be the basis from which staged tariff reductions occur in NAFTA.

More than 40% of the chemicals that the U.S. imports from Mexico come into the country duty-free under the Generalized System of Preferences (GSP). For several chemical sectors, the percentage is well over 70%.

Under the GSP program, the U.S. grants duty-free treat-

U.S. chemical trade patterns with Mexico, Canada differ

	1991 U.S. chemical exports to			1991 U.S. chemical imports from		
$ Millions	Canada	Mexico	Total	Canada	Mexico	Total
Organics	1133	710	11,073	757	249	8,157
Inorganics	508	260	4,160	1025	182	3,299
Dyeing, tanning & coloring materials	487	114	1,660	176	26	1,416
Medicinals & pharmaceuticals	562	121	4,677	118	18	3,053
Essential oils, toilet & polishing preps	532	120	2,430	190	52	1,417
Fertilizers	200	52	2,996	723	15	919
Plastics, primary form	1275	608	7,570	609	44	1,930
Plastics, nonprimary form	768	357	2,817	452	80	1,855
Other	1219	314	6,099	302	55	2,123
TOTAL	**6684**	**2656**	**43,482**	**4352**	**721**	**24,169**

Source: U.S. Bureau of the Census

Mexico's 'primary' petrochemical list

In Mexico, only Petróleos Mexicanos (Pemex) can produce the products on the "primary" petrochemicals list. The U.S. chemical industry would like to see that list abolished, or at least shortened. Mexico's "primary" petrochemicals:

Ammonia
Benzene
Butadiene
Dodecylbenzene[a]
Ethane
Ethylene
Heptane
Hexane
Methanol
n-Paraffins
Pentanes
Propylene
Propylene tetramer
Raw material for carbon black
tert-Amyl methyl ether
Toluene
Xylenes
o-Xylene
p-Xylene

a From propylene tetramer. **Source:** Asociación Nacional de la Industria Química

ment to certain imports from qualified developing countries. Mexico is one of those countries.

If NAFTA eliminated tariffs on all chemicals immediately, GSP would be meaningless for Mexican chemical exports to the U.S. But tariffs on all chemicals certainly won't be eliminated immediately under NAFTA and, until they are, GSP will continue to be an issue.

Mexico undoubtedly will fight to retain its GSP privileges. But Mexico imposes significant tariff barriers on some chemicals, particularly resins, that are eligible for GSP. Noting this, CMA thinks that tariffs on these products should be harmonized immediately.

It is on the tariff issue, however, that there is less harmony within the U.S. chemical industry than there is on most other issues. Many small companies with labor-intensive batch operations think their concern about tariffs isn't getting the kind of attention it deserves from the industry's leading trade spokesmen. The spotlight, they say, is on petrochemicals, investment, intellectual property—"things the big boys want." Meanwhile, the problems of small, batch-type operators go by the boards. It's one of the very few areas in the chemical industry in which Mexico is perceived to have a competitive advantage.

David S. Alcorn, former president of the dyes and chemicals division of Crompton & Knowles and now the company's spokesman on tariff matters, says that, over the past 20 years, many U.S. companies with batch operations have been wiped out by imports. This has meant lost jobs, but the impact is hidden in the overall trade surplus that the chemical industry consistently racks up.

The problem is particularly acute for the few remaining U.S. companies that produce dyes and pigments—products contained in chapter 32 of the Harmonized Tariff System. And, as NAFTA negotiations progress, these companies have their attention focused on the dyes and pigments plants that already are operating in Mexico.

V. M. (Jim) DeLisi, vice president of Fanwood Chemical, in Fanwood, N.J., notes that these dyes and pigment plants in Mexico are not "Mexican" plants, but are predominantly owned by subsidiaries of European multinationals. "They are looking at NAFTA as a possible way to expand in Mexico at the expense of U.S. companies," he says.

Consequently, the batch-process companies in the U.S. want a longer phase-in period for tariff cuts on their import-sensitive products. This is not surprising. Traditionally, dyes and dye intermediates have been listed as import-sensitive products at trade negotiations, including the ongoing Uruguay round of trade talks.

But DeLisi, who also is chairman of the international trade committee of the Synthetic Organic Chemical Manufacturers Association (SOCMA), is concerned about how many products will be allowed on the import-sensitive list, and he's looking for a 15-year phase-in period for Chapter 32 products. CMA's policy statement on tariffs does call for a longer phase-in period for import-sensitive products. But it doesn't specify how long. For the Uruguay round, the industry has suggested a maximum 15-year period for phasing in tariff cuts on import-sensitive chemicals.

To DeLisi, tariffs are not a stand-alone issue. "You have to consider the relationship between tariffs and regulations," he says. And he doesn't mean just environmental regulations, but health and safety regulations, labor regulations—"the whole ball of wax."

It costs money to comply with stringent regulations. And in Mexico, says DeLisi, dyes and pigments plants operate under environmental and other regulations that are nowhere near as stringent as those in the U.S. He believes that these regulatory issues must be addressed in the environmental and labor negotiations that "parallel" the NAFTA negotiations on trade. In the meantime, the phase-in period for eliminating tariffs on these batch products should be as long as it takes for Mexico to bring its regulations up to par with U.S. regulations.

It doesn't surprise DeLisi that the Mexicans are pushing very hard to get favorable tariff treatment in NAFTA for these Chapter 32 products. And it's no surprise that he and his colleagues are working just as hard to see that these products are treated "fairly" during the negotiations.

Because Canada produces very few of these products, the U.S.-Canada trade agreement was a "nonevent," says DeLisi. Consequently, little was heard from this industry. NAFTA, however, is a "serious" event and the remaining U.S. batch operators are treating it as such. And the way to treat it, says DeLisi, is to link tariff with regulations.

Much of that effort will come through SOCMA, some of whose members are the small companies that use batch processes. But Susan Kernus, SOCMA's manager of government relations, emphasizes that this does not put the association at odds with the rest of the chemical industry about NAFTA. SOCMA is a member of OCITA, as is CMA. And SOCMA, she says, has been a strong supporter of NAFTA, along with the rest of the industry. In this case, it's just a question of emphasis, she says.

One link that is important to the chemical industry is that between tariffs and nontariff barriers. In the Uruguay round, the industry has stressed that there should be no tariff cuts without eliminating or reducing the nontariff barriers that also impede the free flow of goods among countries. That's also true in NAFTA negotiations.

Among the nontariff barriers that trouble the industry are import quotas and licenses, import permits, and technical standards designed to favor domestic industries over imports. CMA believes NAFTA should allow only those governmental charges on imports that are consistent with GATT.

Although petrochemicals, investment, and tariffs rank high on the list of the industry's concerns about NAFTA, they certainly aren't the only ones. The chemical industry wants NAFTA to provide good protection for intellectual property rights. This would include comprehensive product and process patent coverage and a minimum of compulsory licensing.

It wants a dispute settlement process that is transparent, uncomplicated, and binding. The agreement also should specify a reasonable time limit for resolving disputes.

The U.S. chemical industry also wants NAFTA to provide strong "rules of origin" so that the benefits of liberalization go to the industries of the three countries and not to outsiders. Normally, such rules contain a "territorial value test." This test specifies that a certain percentage of a product's value must be added within the trade area to qualify for preferential tariff treatment.

Such a rule can be complicated, however. Witness the predicament Honda is in with the U.S. Customs Service over the cars it produces in Canada and exports to the U.S. To simplify the procedure, CMA proposes using a "tariff shift" test for chemicals listed in chapters 28 through 40 of the Harmonized Tariff System. If processing a chemical changes it from one tariff classification to another, it would be assumed that the new product automatically meets the territorial value test.

The Canadian and Mexican chemical industries feel the same way. In fact, CMA, the Canadian Chemical Producers' Association, and Mexico's Asociación Nacional de la Industria Química (ANIQ) have issued a joint policy statement on rules of origin for the NAFTA negotiations.

But just because the three trade associations representing their countries' chemical industries agree on something doesn't mean their negotiators also agree. One U.S. chemical trade expert close to the negotiations says Mexican negotiators aren't buying what ANIQ is selling on rules of origin. According to him, Mexican negotiators don't give as much credence to their private-sector advisers as U.S. and Canadian trade officials do.

In fact, virtually all of the chemical industry trade advisers in the U.S. give the U.S. Trade Representative's staff high marks for listening to, understanding, and acting upon their advice. "We couldn't be more pleased with our access to USTR," says CMA's O'Connor.

That doesn't mean that all of that advice will end up in the text of a NAFTA agreement. But at least it gets a sympathetic hearing.

The big question, of course, is will there be a NAFTA accord? And when? The goal was to complete the negotiations by the middle of this month so that the finished package could be sent to Congress with enough time for it to consider it before the elections in November. Given the status of the negotiations now, it will be tough to meet that schedule.

U.S. Trade Representative Carla Hills said recently that it was "absolutely mandatory" that the Administration send Congress a NAFTA text with all the details worked out, not just an outline of an agreement in principle. Some speculate that, even if a complete agreement is reached in this highly charged election year, President Bush may delay sending the agreement to Congress until next year—assuming, of course, that he is reelected. But Hills says she cannot conceive that the Administration would not send the text to Congress as soon as it is ready.

Since their "mega meeting" in Dallas in mid-February, the 19 NAFTA negotiating groups have been hammering away at the contentious issues involved in the negotiations. Considering that the negotiations are only one year old, says Hills, there has been good progress. But she concedes that each of the 19 groups has a difficult issue to cope with and that the energy group, which includes petrochemicals, is particularly difficult.

She also concedes there now is not enough time for Congress to consider an agreement under the formal "fast-track" timetable before the November elections. However, it's also possible that Congress may not need the full 90 calendar days allotted to consider an agreement.

So it's still not clear when—or if—there will be a NAFTA agreement. Meanwhile, chemical industry trade advisers will continue working closely with U.S. trade officials to help shape an agreement they can support.

O'Connor won't speculate on whether the chemical industry will end up supporting a NAFTA agreement when it surfaces. A decision on that support must await the final package that NAFTA negotiators come up with. Says O'Connor, "We started out putting all of our original lofty, but not unrealistic, goals on the table. When it [the negotiations] is over, we must evaluate where the process has taken us and decide if we are better off with the agreement than without it."

However, the Coalition for Trade Expansion recently sent a letter to President Bush expressing its concern that the NAFTA negotiations are not producing positive results in "key areas." CMA is one of 20 trade associations and other trade groups that are members of that coalition.

Worldwide fibers output perks up slightly

World production of man-made fibers—which include both synthetics and cellulosics—last year rose slightly more than 1% from 1990 to a historic high of about 19.3 million metric tons, according to the annual fibers survey just released by Dutch chemicals and fibers producer Akzo.

Synthetic fibers, including polyester, nylon, and acrylic, accounted for 84% of the total production, 16.2 million metric tons, up from almost 15.9 million metric tons in 1990. Cellulosic fibers—mostly acetate and viscose fibers—fell to 16% of world production or 3.07 million metric tons, down from the 17% share or 3.22 million metric tons produced in 1990. In total, says Friedrich W. Fröhlich, president of Akzo's fibers division, man-made fibers make up more than half of all fibers consumed worldwide (the remainder is accounted for by natural fibers, such as cotton and wool). In industrialized countries, man-made fibers' share is more than two thirds.

According to Fröhlich, 1991 growth in man-made fiber production came from "other regions" outside the industrialized world, with those regions accounting for 54% of world production. Growth in these regions in 1991 was concentrated in Southeast Asia. In fact, he points out, Taiwan now produces more man-made fibers than either Japan or China. The production level of such nonindustrialized countries now is five times higher than it was 20 years ago, three times higher than current production in Western Europe, and nearly three times greater than in the U.S. now. (The Western Europe designation in Akzo's report comprises European Community countries including the former East Germany, and nations belonging to the European Free Trade Association.)

U.S. production of man-made fibers in 1991 was 3.72 million metric tons, essentially unchanged from 1990. Japan raised domestic production 1% to 1.82 million metric tons. In Western Europe, production declined 6% to 3.41 million metric tons, and that of Eastern Europe also fell. Fröhlich notes that "output in Eastern Europe is difficult to estimate, but it is certainly experiencing a downward trend." Akzo estimates this annual decline to be more than 10% in 1991, and company marketers glumly refer to that market as having disappeared.

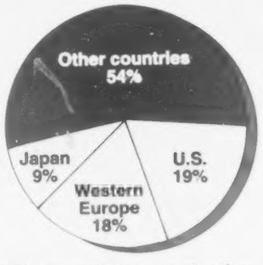
One of the factors contributing to the decline of production in Western Europe, Akzo believes, is that the region continues to be heavily targeted for imports. Imports into Western Europe last year reached a record level of 2.7 million metric tons, twice the level in 1985. At the same time, exports have declined. In addition, Western European export markets were hit as Southeast Asian producers substantially increased their capacities, becoming increasingly competitive in world markets.

According to the Akzo survey, the net 1% increase in man-made fibers came solely from growth in production of synthetic fibers, which rose 2%, especially on strong growth of polyester fibers. A 4% decline in production of cellulosic fibers was concentrated in Western and Eastern Europe.

Nylon, as well as cellulosics, lost ground in Western Europe, whereas other synthetic fibers, including acrylics, posted increases. In the U.S., cellulosics output was down slightly, and production of nylon and most other synthetics—particularly those used in the carpet industry—posted large declines. Only strong production in polyester fibers boosted net production into positive growth. In Japan, a slight decline in nylon fiber output was offset by increases in all other fiber types.

In fact, in 1991, of all synthetic fibers, only nylon showed a net output decline worldwide, the Akzo survey shows, falling to 23% of total world production of synthetic fibers from 24% the year before. Polyester had a good year, boosting share of worldwide production to 55% in 1991 from 54% in 1990. And acrylics production, which had been battered in 1990 because of a variety of fashion trends, increased, although its share of total worldwide output declined to 14% from 15% the year before.

Developing nations make half of world's fibers



1991 worldwide production of man-made fibers = 19.3 million metric tons

Source: Akzo

And for the category that Akzo calls "other synthetic fibers," which includes polypropylene and elastane fibers, production rose to 1.54 million metric tons from 1.34 million metric tons in 1990, or 8% of total 1991 production.

In reporting specifically on the performance of Akzo's fiber division, Fröhlich emphasizes the division "closed 1991 with black figures. This can certainly not be said about all of our competitors." Business was down, however. The summer, in particular, "was very bad, worse than we had expected," he says.

The division's sales in 1991 were $2.47 billion, down 12% from 1990. Operating profits were $59 million, a drop of 53%. And shipments were 337,000 metric tons through the year, down from 400,000 metric tons in 1990. Among the specific factors Fröhlich cites: recession in the major countries and industries in which the unit's customers operate; high imports; disappearance of Eastern European markets; export problems caused by unfavorable currency exchange rates; and high cost increases, especially with regard to labor costs.

Emphasis on viscose fibers, industrial fibers (particularly tire cord), and work force reductions are among Akzo's countermeasures. For example, it has reached agreement with the Treuhandanstalt, the German government agency charged with privatizing enterprises in the former East Germany, to assume management and sales at the textile viscose fiber plant at Elsterberg. According to Fröhlich, Akzo has a takeover option as well.

In tire cord, the company has elected to discontinue its steel cord production and concentrate on rayon and polyester cord. For example, last year it acquired Goodyear's polyester cord plant in Scottsboro, Ala.

And, in part by a discontinuation of some activities, it has reduced its work force by about 18% to 21,000 over the course of the year. By the end of 1992, Fröhlich adds, further reductions will take that to fewer than 20,000 employees.

Patricia Layman

True Employment Situation for Chemical Professionals Uncertain

The American Chemical Society's Committee on Professional Relations (CPR) continues to be concerned that its long-established approach to investigating and reporting on mass terminations of chemical professionals may be understating the seriousness of unemployment among chemists, especially older ones.

CPR's latest report, the 33rd in a series dating back to 1974, details five such terminations involving 102 chemical professionals. But it also points out that 15 unverified terminations, involving as many as 250 people, are under investigation.

One of the particular concerns of CPR is the reluctance of individuals terminated to cooperate in such investigations. Another is the problem of differentiating between involuntary and voluntary terminations. Traditionally, CPR counts only terminations that are unambiguously involuntary. It does not count the apparently increasing number of chemists involved in recent years in early retirement and other schemes designed to encourage "voluntary" separation from an employer. As one chemist involved in such a situation reported to CPR, his termination was "voluntary but with no viable alternative."

CPR is also unhappy about a recent ruling of the Court of Appeals of the 2nd Circuit in New York City, that employers can fire older executives to trim costs if each termination is handled individually on its merits and is based solely on financial considerations. The committee describes the timing of this decision as "unfortunate."

The five mass terminations covered in the latest report range in size from 40 terminated workers at Henkel Research in Santa Rosa, Calif., down to seven terminees at Ciba-Geigy in Hawthorne, N.Y. The terminations occurred between October 1990 and March 1991. CPR defines a mass termination as a situation in which three or more chemical professionals are terminated within a six-

Employer compliance with ACS employment guidelines

These employers provided information	Approximate number of employees separated	Advance notice	Severance pay	Assistance	Employee service	Protection plans
Ciba-Geigy (Hawthorne, N.Y.)	7				▨	
Henkel Research (Santa Rosa, Calif.)	40		▨			▨
Mead Imaging (Miamisburg, Ohio)	23		▨			▨
Petrolite (St. Louis, Mo.)	13	▨			■	▨

This employer provided no information						
EniMont America (Monmouth Junction, N.J.)	19				na	▨

na = not available

☐ Employer met or exceeded guideline standard.

▨ Two or more individuals below guideline standard, but average experience better than "substantially below" criterion.

■ Employer was substantially below guideline standard, which is defined as follows:

- Advance notice—less than four weeks.
- Severance pay—less than two weeks per year of service.
- Assistance—no assistance rendered.
- Employee service—more than 30% of terminees had 10 or more years of service.
- Protection plans—no continuation of protection plans.

ACS guidelines

- **Advance notice.** Four-week minimum.
- **Severance pay.** Minimum is two weeks per year of service. Additional notice may be given, by mutual agreement, in lieu of severance pay.
- **Assistance.** Efforts should be made to place terminee in another position within the organization, or terminee should be given assistance to find employment elsewhere.
- **Employee service.** Those with minimum of 10 years' service should not be terminated except for continued evidence of previously documented inadequate performance or cause.
- **Employee protection plans.** Should be extended for a minimum of one month, plus two weeks for each year of employee service, following termination, at same rate of contribution as before. Employee would have additional 31-day grace period.

month period for reasons other than properly documented inadequate performance, the end of a contract, or cause.

As is usual, CPR compared the performance of the employers involved in the five terminations with standards contained in ACS's Professional Employment Guidelines (PEG). Compliance was higher than usual, 63%. This compares with an average 41% for the previous 32 reports.

All five employers involved met the guidelines for assisting those fired in seeking other employment. At the other end of the compliance scale, only one employer met the PEG standard for extending health and other protection plans for a period beyond termination.

CPR requests that chemical professionals who have been fired or who have taken involuntary early retirement contact the American Chemical Society, Office of Professional Services, 1155—16th St., N.W., Washington, D.C. 20036. Copies of all CPR termination reports and of related C&EN stories are available, on request, from the same office.

Michael Heylin

Nominations sought for Stone Award

The ACS Carolina-Piedmont Section is requesting nominations for the Charles H. Stone Award. This award, which consists of a plaque, $1000 honorarium, and travel expenses to the award banquet and presentation, is given to a chemist in the ACS Southeast Region upon nomination and selection by the Stone Award committee.

Nominating material should include a letter of nomination, seconding letters, biographical sketch, and other supporting documents. Send to Paul Rillema, Department of Chemistry, University of North Carolina, Charlotte, N.C. 28223. All material should be received no later than May 15. ☐

Fellowship in rubber and polymer science

The ACS Rubber Division has announced the availability of its $10,000 Paul J. Flory Memorial Fellowship for a student now working toward a postgraduate-level education in rubber and polymer science. Originally established in 1988 to perpetuate the tradition of outstanding scientific research practiced by Nobel Laureate Paul J. Flory, the fellowship award is sponsored by the Education Committee of the Rubber Division.

Candidates may be nominated by a professor or a department active in graduate-level rubber and polymer science. Names of doctoral-level candidates should be submitted by May 31 with the following information: undergraduate and graduate transcript, a research proposal that describes anticipated project activity, candidate's statement describing how this endeavor would fit into his or her career plans, and recommendation from the thesis adviser.

For additional information contact Education Committee, ACS Rubber Division, P.O. Box 499, Akron, Ohio 44309-0499, phone (216) 972-7814. ☐

AWARDS

Special recognition to . . .

The American Institute of Chemical Engineers has presented several awards to honor outstanding contributions by chemical engineers. James E. **Bailey,** Chevron Professor of Chemical Engineering, California Institute of Technology, is the recipient of the 1991 Food, Pharmaceutical & Bioengineering Division Award. Bailey was cited as "an expert in biochemical engineering—specifically, the engineering of cells to improve their effectiveness in process applications." The award consists of a certificate and a $2500 honorarium.

John L. **Hudson,** Wills Johnson Professor of Chemical Engineering, University of Virginia, Charlottesville, has won the R. H. Wilhelm Award in Chemical Reaction Engineering for his contributions to chemical reaction research and education. Given annually, the $3000 award recognizes "significant and new contributions in chemical reaction engineering."

Robert **Langer,** Germeshausen Professor of Chemical & Biomedical Engineering, Massachusetts Institute of Technology, is the winner of the Charles M. A. Stine Award in Materials Engineering & Sciences. Author of some 275 technical publications and holder of 73 patents, Langer developed the first controlled-release systems for proteins and bioerodible polymers.

Michael L. **Mavrovouniotis,** assistant professor, University of Maryland's Systems Research Center and chemical engineering department, College Park, is being honored with the Ted Peterson Student Paper Award. An expert in computer-aided engineering of chemical and biochemical processes and systems, he is receiving the award for his paper, "Computer-Aided Synthesis of Biochemical Pathways."

John A. **McBride,** retired senior vice president, E. R. Johnson & Associates, Oakton, Va., is the recipient of the Robert E. Wilson Award in Nuclear Chemical Engineering. He was cited for "his expertise in process and product development and quality assurance related to nuclear engineering." McBride has 47 years of experience in the field, having served with Phillips Petroleum Co. and the U.S. Atomic Energy Commission before joining E. R. Johnson.

John R. **McWhirter,** professor of chemical engineering, Pennsylvania State University, has won the Arthur Dehon Little Award for Chemical Engineering Innovation. He is being recognized as an "expert in environmental engineering, gas-liquid mass transfer, and oxygen transfer in biochemical oxidation processes." Before joining the faculty at Penn State, he spent most of his career at Union Carbide, where he developed and marketed the UNOX process for improving wastewater treatment.

Donald F. **Othmer,** professor emeritus, Polytechnic University, Brooklyn, N.Y., is the winner of the 1991 Founders Award for Outstanding Contributions to Chemical Engineering. Othmer is well known for his pioneering work in designing chemical processes and manufacturing facilities for mass production of chemical products, as well as for his career as a chemical engineering educator. He is credited with helping to mass produce aspirin and cellulose acetate, and holds more than 150 domestic and foreign patents.

Michael L. **Shuler,** professor of chemical engineering, Cornell University, has received the Professional Progress Award for his accomplishments in bioreactor development for plant cell tissue cultures, for pioneering a new class of mathematical models for living cells, and for applied genetic engineering. Presented annually, the award consists of a $4000 honorarium and $500 travel allowance.

Richard D. **Siegel,** a principal and director of business development, ENSR Consulting & Engineering, Acton, Mass., is being honored with the T. J. Hamilton Memorial Award for Government Service for his expertise in environmental engineering—particularly in air pollution control

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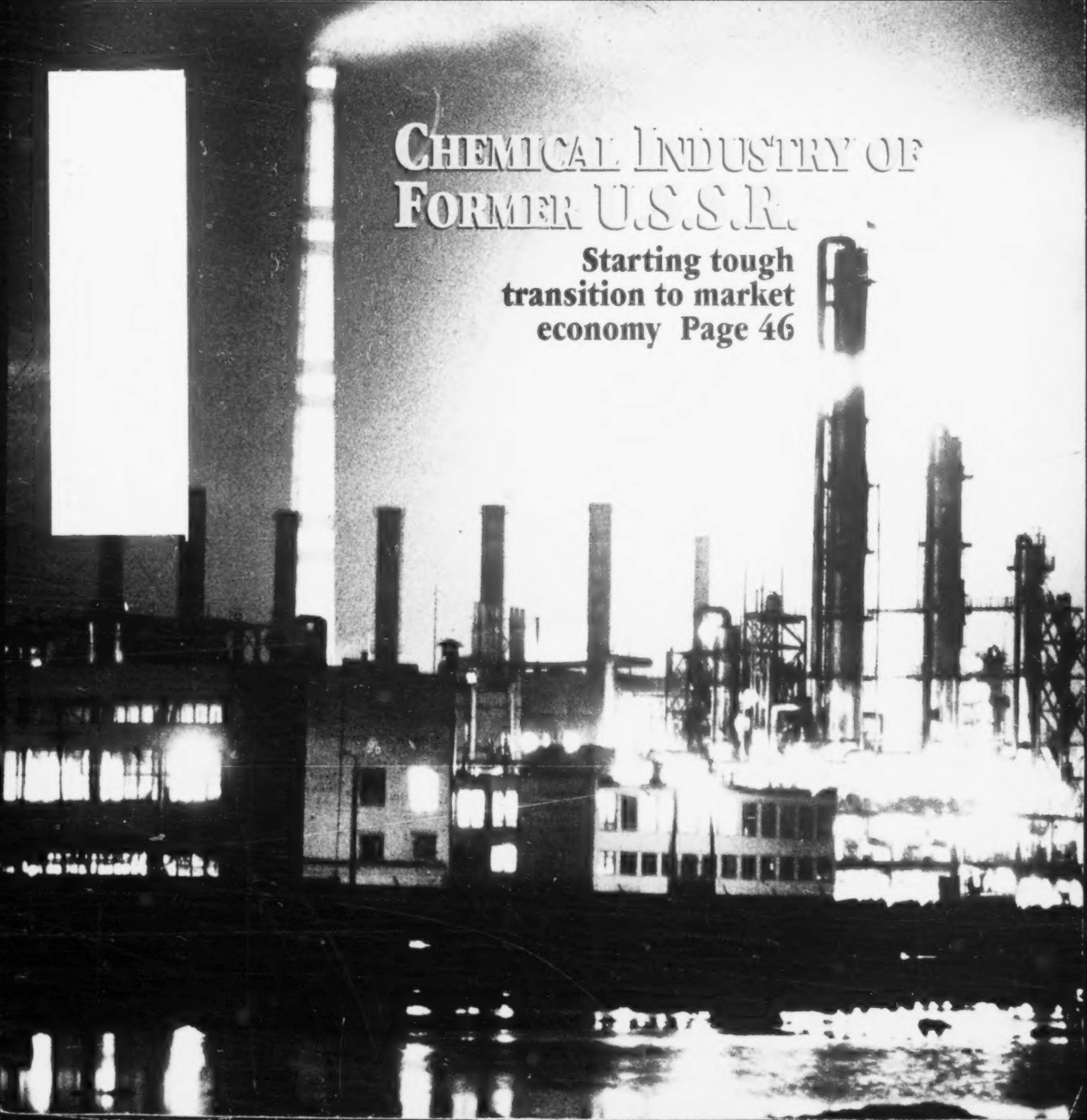
CHEMICAL & ENGINEERING NEWS

C&EN

APRIL 13, 1992

TOP 50 CHEMICAL PRODUCTION CHANGED LITTLE LAST YEAR PAGE 16



CHEMICAL INDUSTRY OF FORMER U.S.S.R.

Starting tough transition to market economy Page 46

CHEMICAL & ENGINEERING NEWS
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NEWS OF THE WEEK

- House hearings probe how government sets research priorities. **Page 4**
- ACS national meeting in San Francisco last week set records in attendance and in the size of its technical program. **Page 4**
- Herman Mark, a founding father of polymer science, dies at 96. **Page 5**
- New light-sensing device based on molecular dye and high-temperature superconductor can respond selectively to different colors of light. **Page 6**
- Immunex is suing Hoechst A.G. and two subsidiaries over GM-CSF, a drug to stimulate white blood cell growth. **Page 6**
- Preparatory negotiations for UN Conference on Environment & Development end with major issues unresolved, dimming prospects for global agreements to protect the environment. **Page 7**
- Astronauts on space shuttle study atmospheric chemistry during nine-day mission. **Page 7**
- Two new approaches to making the anticancer drug taxol have been devised. **Page 8**

COVER: Nizhnekamsk Petrochemical Combine, located in the Volga region of Russia, is the republic's largest source of ethylene. Photo by TASS/SOVFOTO

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ISSN 0009-2347

BUSINESS

Production of Top 50 chemicals stagnates in 1991, with organic production increasing only 3% and inorganic production decreasing 1%. **Page 16**

Polymer production edged up a bit more than 1% in 1991 from 1990 to a new high of 62.8 billion lb. **Page 20**

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Federal R&D budget faces cutbacks following Congressional votes to retain the budgetary "fire walls" that prohibit the swapping of funds among defense, domestic, and international programs. **Page 27**

National Academy of Sciences panel will consider feasibility of methods other than incineration for the destruction of chemical weapons. **Page 29**

New payment option to recipients of National Science Foundation Young Investigator awards offers maximum flexibility, especially for leveraging matching funds from industry. **Page 30**

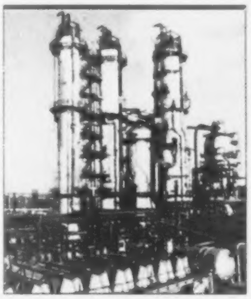
SCIENCE/TECHNOLOGY

Polyrotaxanes, unusual complexes with two dozen or more cyclodextrin rings threaded on a polymer chain, may have applications in molecular technologies and materials science. **Page 39**

Environmental regulatory activity is becoming more realistic, as was emphasized by both keynote speakers at AIChE's recent annual meeting. **Page 41**

A new predoctoral fellowship program will provide funds to universities to support interdisciplinary training of Ph.D. students in chemistry and biology. **Page 44**

SPECIAL REPORT



Chemical industry in the former Soviet Union, one of the largest and yet one of the most backward and inefficient industries in the world, must make a difficult transition to a market economy. Page 46

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
(For list of offices see page 85)

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LETTERS

Cold fusion research

Eugene Mallove (C&EN, Feb. 10, page 2) accuses Trevor Pinch and me of "arrogant misunderstanding of cold fusion research." Casting his net further, he then accuses the scientific establishment and some science media of "arrogant dismissal" of a "new phenomenon of unparalleled signficance," because we regard it as "a priori impossible." The latter, at least, is untrue, as should be apparent to anyone who read even the first three pages of "Too Hot to Handle," where I wrote, "Even though intuitive[ly we felt] that [cold fusion] was too far-fetched to be real, nonetheless it had to be checked." Mallove seems to have forgotten that vast numbers of institutions, including Department of Energy-sponsored laboratories in the U.S., Harwell Laboratory in the U.K., and other European national facilities indeed made such checks by investigating the cold fusion claims in 1989. This is hardly consistent with "a priori" dismissal.

I hope that our lack of belief in cold "fusion" is not due to arrogance, but instead to the cold-blooded analyses by many physicists, metallurgists, and chemists. The majority of scientists have now moved on from cold fusion, the revelations in "Too Hot to Handle" having tied up some of the loose ends and having raised further doubts about the original Martin Fleischmann, Marvin Hawkins, and B. Stanley Pons claims. Since writing "Too Hot to Handle," I have continued to monitor the cold fusion work, much of which is, indeed, extraordinary (though not perhaps in the sense that Mallove meant).

This leads me to the following summary of the present evidence and suggests possible interpretations. First, some cells have shown thermal balance with either light or heavy water. This set of results is showing either that there is no "cold fusion" effect at all, or that there is an unknown trigger that is missing in these "dead" cells. Second, other cells have shown thermal imbalance both with heavy water and also with ordinary water. This set of phenomena arises either because there is miscalibration or because these cells contain the unknown trigger. The electrochemical community has to decide on the former. In order to retain contact with Mallove, let's suppose that the latter is correct. My conclusion is that this trigger has the features of chemical/atomic and not nuclear reactions because the effect is of similar magnitude with heavy and light water and no nuclear products have been found commensurate with the claimed amounts of heat.

The "well-established . . . tritium, neutrons, charged particles" cited by Mallove are less impressive than his letter might suggest: They are seen sporadically, if at all, in uncorrelated fashion, and fail by orders of magnitude to be nuclear products from watts of power. If, as Mallove claims, the heat is reproducible, and if it is nuclear fusion (or even a nuclear "process" as the original proponents now seem to be retreating to), then the original materials turn into something—and so, I ask, why do we hear so little about these remnants? Findings of the order of 10^{12} nuclear transmutations per watt should be relatively easy, and, if found reproducibly, would prove the claims beyond all doubts. It is the strange reluctance to do this definitive test, or the a posteriori excuses when the products do not show up, that strain credibility and help to make me a skeptic.

There have been—and are still—claims to find neutrons at a level over a billion times below these. This is still under investigation by Stephen Jones and others, as great care is needed to distinguish such a weak signal from the natural background radiation. If real (and many nuclear physicists are yet unconvinced), these have no bearing on the heat claims by Fleischmann, Hawkins, and Pons, and it is misleading to lump all these together. Indeed, Jones has repeatedly distanced his work from that associated with the three researchers.*

Finally, there is the myth of hundreds of papers supporting cold fusion. But many of these are, in Herman Feshbach's words, "a bunch of junk." I have discussed as many as practically possible with experts in various fields and conclude that there are perhaps a few dozen at most that merit a second look—but even among these there is no correlation, nor any one that stands out as a landmark. One claims tritium but no neutrons, and another claims neutrons that are statistically insignificant and no tritium; one claims heat with helium as a byproduct, and another claims heat and no products. Yet another claims heat with ordinary water, and so on. To some this is a tantalizing hint of "esoteric reactions that violate conventional theories of physics"

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Top 50 Chemicals Production Stagnated Last Year

■ ***Although output was virtually unchanged from 1990, organics production moved up 3% while that of inorganics declined 1%***

Marc S. Reisch,
C&EN Northeast News Bureau

The economic slowdown finally caught up with chemical producers in 1991. Chemical export growth was not enough to counter the lag in most industrial markets or to help push U.S. chemical production to new heights in 1991, as it did in 1990.

According to C&EN's annual ranking of the 50 largest volume chemical products, total production in that group was virtually unchanged in 1991 from 1990. Production stagnated at the 633 billion-lb level registered the year before, which had been a good year. In 1990, production of the Top 50 rose 2% over 1989.

The Federal Reserve Board's data for 1991 also portray a commodity chemical slowdown. The Federal Reserve's seasonally adjusted indexes for basic and industrial chemical production increased less than 1%, respectively, between December 1990 and December 1991. And just as C&EN's Top 50 showed production gains in 1990 compared with 1989, Federal Reserve data indicate that between December 1989 and December 1990 seasonally adjusted basic and industrial chemical production increased (7% and 3%, respectively).

A year such as 1991 demonstrates just how much the cycle for commodity chemicals differs from that for other chemicals—for instance, specialty and pharmaceutical chemicals. These two categories are not included among C&EN's Top 50. However, the Federal Reserve's seasonally adjusted indexes show high-value pharmaceutical chemicals production rose almost 10% between December 1990 and December 1991. And plastic materials production, for instance, increased 5% during the same period.

Although the Top 50 in some ways reflects the general slowdown in business and the economy, commodity chemicals production is more a lagging indicator of economic conditions like

About the Top 50 list of chemical products

Government data, trade association figures, and industry estimates all go into preparing C&EN's annual list of the Top 50 chemical products, ranked by production volume. The federal government is relied upon most heavily, but when government figures are not available, other sources, primarily trade associations, are used. Industry sources and C&EN estimates are used only when other data are lacking.

Government data are not always accurate—they are only as good as the information that individual companies report. But they are an objective measure of production extending back many years. Therefore, relatively accurate indications of growth can be made on a consistent basis.

At this time of year, C&EN has access only to preliminary reports of production for 1991. When the government and trade associations issue their final reports, the outcome can be changed, sometimes dramatically. As a result, the production figures for earlier years that appear in the table on page 17 are different in some cases from those published in last year's Top 50 article. The final reports also can affect the rankings of chemicals. For the table on page 17, the 1990 ranking of 20 chemicals is different from last year's listing (C&EN, April 8, 1991, page 14).

The list itself covers production figures for the U.S. and includes chemicals produced for export. Candidates for the list include all basic, intermediate, and chemically homogeneous finished products. These range from chemical building blocks like ethylene and propylene to downstream products like vinyl acetate and ethylene glycol.

The roster includes basic inorganic chemicals, but does not include what C&EN considers to be minerals, such as salt, gypsum, and sulfur. Lime is included because it is processed and has many chemical and industrial applications. Refractory (dead burned) dolomite is excluded in lime production.

On the organics list, such petrochemical feedstocks as ethane, butane, and propane are excluded arbitrarily because they are considered to be products of oil companies and because they have many nonchemical uses.

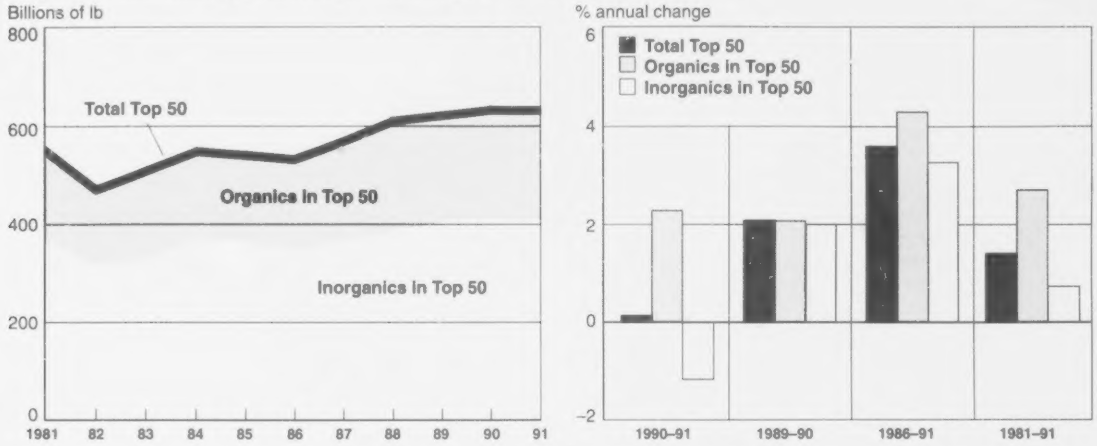
There are other gray areas besides lime and petrochemical feedstocks. For example, the basic aromatics—benzene, toluene, and xylene—are included.

Production figures are published by the government in a variety of units—pounds, tons, cubic feet, gallons, metric tons, and most recently, kilograms and liters. Where the latter two units are used, they have been converted, where appropriate, into the common units that the government and industry have historically used as points of reference. To provide an accurate ranking and to make comparison of production volumes easier, C&EN lists production not only in common units, but also by weight in pounds.

Top 50 chemicals production totaled about 633 billion lb last year

Rank			Billions of lb		Common units[b]		Average annual change			
1991	1990[a]		1991	1990	1991	1990	1990–91	1989–90	1986–91	1981–91
1	1	**Sulfuric acid**	86.62	88.09	43,308 tt	44,044 tt	-1.7%	1.7%	3.8%	0.6%
2	2	**Nitrogen**	57.03	56.23	787 bcf	776 bcf	1.4	4.3	3.2	4.9
3	4	**Ethylene**	39.23	36.47	39,231 mp	36,473 mp	7.6	4.2	3.6	2.9
4	3	**Oxygen**	38.99	40.48	471 bcf	489 bcf	-3.7	8.2	3.4	0.9
5	6	**Ammonia**	34.04	33.59	17,020 tt	16,796 tt	1.3	2.0	4.0	-1.1
6	5	**Lime**[c]	33.60	34.90	16,800 tt	17,452 tt	-3.7	1.6	3.0	-1.1
7	7	**Phosphoric acid**	24.68	24.07	12,342 tt	12,034 tt	2.6	2.5	6.0	2.2
8	8	**Sodium hydroxide**	24.39	24.06	12,197 tt	12,030 tt	1.4	4.9	2.7	1.6
9	9	**Chlorine**	22.65	23.62	11,324 tt	11,810 tt	-4.1	3.5	1.6	0.5
10	10	**Propylene**	22.02	21.85	22,024 mp	21,849 mp	0.8	6.2	5.9	5.0
11	11	**Sodium carbonate**[d]	20.50	20.18	10,249 tt	10,090 tt	1.6	1.8	4.0	2.2
12	12	**Urea**[e]	16.14	16.24	8,072 tt	8,120 tt	-0.6	1.4	6.0	0
13	13	**Nitric acid**	15.05	16.00	7,524 tt	7,999 tt	-5.9	-4.2	2.8	-1.9
14	14	**Ammonium nitrate**[f]	14.62	14.16	7,310 tt	7,081 tt	3.2	-10.0	5.6	-1.9
15	15	**Ethylene dichloride**	13.92	13.85	13,922 mp	13,852 mp	0.5	3.5	1.5	3.4
16	16	**Benzene**	11.78	12.45	1,600 mg	1,690 mg	-5.3	4.2	3.3	2.0
17	17	**Vinyl chloride**	11.70	10.63	11,695 mp	10,626 mp	10.1	4.8	6.7	5.5
18	18	**Carbon dioxide**[g]	9.76	10.37	4,882 tt	5,186 tt	-5.9	-2.9	0	2.6
19	19	**Methyl *tert*-butyl ether**	9.60	8.89	9,600 mp	8,886 mp	8.0	8.0	23.3	28.9
20	20	**Ethylbenzene**	9.22	8.37	9,221 mp	8,370 mp	10.2	-9.4	0.4	1.7
21	22	**Styrene**	9.01	8.02	9,005 mp	8,017 mp	12.3	-3.9	2.7	3.0
22	21	**Methanol**	8.65	8.35	8,655 mp	8,346 mp	3.7	2.2	3.7	0.1
23	23	**Terephthalic acid**[h]	7.66	7.77	7,656 mp	7,775 mp	-1.5	-7.8	-0.1	2.1
24	25	**Toluene**[i]	6.80	6.21	937 mg	856 mg	9.5	6.9	8.9	1.0
25	24	**Formaldehyde**[j]	6.43	6.72	6,425 mp	6,721 mp	-4.4	14.0	3.0	1.2
26	26	**Xylene**	6.13	6.21	851 mg	862 mg	-1.3	-4.5	6.4	-0.3
27	27	**Hydrochloric acid**	5.60	6.03	2,799 tt	3,013 tt	-7.1	-7.8	3.2	0.8
28	29	***p*-Xylene**	5.43	5.20	5,433 mp	5,202 mp	4.5	-2.7	1.5	1.8
29	28	**Ethylene oxide**	5.24	5.36	5,243 mp	5,356 mp	-2.1	6.4	-0.7	0.2
30	31	**Ethylene glycol**	4.93	5.07	4,930 mp	5,072 mp	-2.8	-7.1	0.7	1.8
31	30	**Ammonium sulfate**	4.46	5.08	2,230 tt	2,539 tt	-12.2	6.5	1.3	0.2
32	32	**Cumene**	4.28	4.31	4,284 mp	4,311 mp	-0.6	-2.6	2.7	2.6
33	33	**Potash**[k]	3.90	3.78	1,770 tmt	1,713 tmt	3.3	7.4	8.0	-2.0
34	34	**Acetic acid**	3.61	3.75	3,612 mp	3,751 mp	-3.7	13.9	5.8	1.6
35	36	**Propylene oxide**	3.60	3.20	3,600 mp	3,200 mp	12.5	0	7.7	6.9
36	35	**Phenol**[l]	3.49	3.54	3,486 mp	3,539 mp	-1.5	-7.0	2.3	3.1
37	37	**Butadiene**[m]	2.91	3.09	2,913 mp	3,089 mp	-5.7	-1.1	2.7	-0.2
38	38	**Carbon black**	2.72	2.87	2,723 mp	2,868 mp	-5.1	-1.5	1.0	0
39	39	**Acrylonitrile**	2.65	2.68	2,648 mp	2,677 mp	-1.1	13.2	3.9	2.9
39	40	**Vinyl acetate**	2.65	2.66	2,646 mp	2,659 mp	-0.5	4.2	9.1	3.2
41	42	**Aluminum sulfate**	2.36	2.45	1,180 tt	1,227 tt	-3.8	-1.3	-0.7	-0.9
42	41	**Cyclohexane**	2.31	2.46	2,309 mp	2,461 mp	-6.2	8.3	2.2	2.4
43	44	**Titanium dioxide**	2.19	2.15	1,093 tt	1,077 tt	1.5	-2.2	3.4	3.7
44	43	**Acetone**	2.13	2.33	2,130 mp	2,331 mp	-8.6	-7.7	1.9	-0.1
45	45	**Sodium silicate**	1.79	1.76	894 tt	880 tt	1.6	5.6	2.5	1.5
46	46	**Adipic acid**	1.56	1.62	1,560 mp	1,620 mp	-3.7	-1.2	0.5	1.2
47	47	**Sodium sulfate**[n]	1.54	1.57	768 tt	786 tt	-2.3	4.1	-0.2	-3.6
48	48	**Isopropyl alcohol**	1.30	1.38	1,297 mp	1,380 mp	-6.1	-6.4	-0.1	-2.5
49	50	**Calcium chloride**[o]	1.29	1.38	644 tt	690 tt	-6.7	-13.9	-3.8	-3.5
50	49	**Caprolactam**	1.28	1.38	1,283 mp	1,380 mp	-7.0	5.5	3.0	3.3
TOTAL ORGANICS			225.67	220.05			2.6%	2.1%	4.3%	2.7%
TOTAL INORGANICS			407.77	412.82			1.2%	2.0%	3.3%	0.7%
GRAND TOTAL			633.44	632.87			0.1%	2.1%	3.6%	1.4%

a Revised. **b** tt = thousands of tons, **bcf** = billions of cubic feet, **mp** = millions of pounds, **mg** = millions of gallons, **tmt** = thousands of metric tons. **c** Except refractory dolomite. **d** Natural and synthetic. **e** 100% basis. **f** Original solution. **g** Liquid and solid only. **h** Includes both acid and ester without double counting. **i** All grades. **j** 37% by weight. **k** K_2O basis. **l** Synthetic only. **m** Rubber grade. **n** High and low purity. **o** 75% basis, solid and liquid.



Top 50 chemicals production unchanged in 1991

unemployment levels. According to the Department of Labor, seasonally adjusted unemployment levels rose during 1991. However, other government data indicate prospects for a recovery. For instance, housing starts began to swing upward in 1991 from their depressed level of 1990, according to the Department of Commerce.

Other measures of the economy also show evidence of new vigor. The Federal Reserve reports that seasonally adjusted auto and light truck production rose 12% between the fourth quarter of 1990 and the fourth quarter of 1991. (However, production of all transportation equipment declined 2% between 1990 and 1991.) Textile mill production increased 6%, and paper and paper products were up 2% during the same period, according to the Federal Reserve. All of these are big markets for chemicals.

Although these industries are all customers of Top 50 products, shipments still lag. Chemical and allied products shipments were down about 1% between December 1990 and December 1991, according to the Commerce Department. Meanwhile, chemical producers' inventories increased about 2%. So while the chemical industry has kept up production to meet an anticipated recovery in demand, the commodity chemicals business has not recovered enough to take advantage of those inventories.

A broad segment of industry economists believe chemical exports were a major factor in the growth of commodity chemicals production in 1990. U.S. exports of all chemicals rose 7% to 38.9 billion lb in 1990 from their 1989 level, according to the Commerce Department. But despite an estimate by the Chemical Manufacturers Association (CMA) that sets U.S. chemical exports at \$44 billion for 1991, production recorded in 1991 for the Top 50 chemicals hardly changed from the previous year. If CMA's estimate proves sound, then exports probably kept 1991 from becoming a year in which commodity volumes declined significantly.

Among the largest volume chemicals produced in the U.S., sulfuric acid remains at the top with total production of 86.6 billion lb, down nearly 2% from 1990. The decline follows an approximate 2% rise from the previous year. For 1991, nitrogen continues to rank a distant number two, with production at 57 billion lb, up slightly more than 1% from 1990. Nitrogen's rate of growth slowed from 1990 when production rose a little more than 4% compared with 1989.

Of the Top 50, the 29 organic chemicals accounted for some 36% of total production, compared with almost 35% in 1990. The combined organics production increased nearly 3% in 1991 from the previous year, after a 2% rise in 1990. Over the five-year period 1986–91, combined production of organic chemicals among the Top 50 increased an average of a little over 4% a year. Historically, though, their output has grown at a slower pace. Between 1981 and 1991, combined output of organic chemicals among the Top 50 grew at a compound annual rate of almost 3% a year.

While organic chemical production continued to grow in 1991, inorganic chemical production declined compared with the previous year. Combined output of inorganics on the list declined a bit more than 1% from the previous year, following a 2% rise in 1990. Over the five-year period from 1986–91, combined production of inorganic chemicals grew at an average annual rate of 3% a year. Like theorganics group, inorganics production historically has grown at a slow pace: less than 1% between 1981 and 1991.

For organic chemicals, 11 of the 29 on the Top 50 list posted production increases. Organic chemical growth in 1991 was led by propylene oxide, production of which rose nearly 13% from 1990 to an estimated 3.6 billion lb. As a result, propylene oxide production moved to 35th place on the 1991 list from 36th place in 1990. Styrene production also grew at a double-digit pace, up 12% in 1991 to 9 billion lb. Styrene's strong growth moved it to 21st place on the Top 50 list from 22nd place in the previous year. Ethylbenzene production increased slightly more than 10% from 1990 to 9.2 billion lb, but its 1991 rank was the same as in 1990: It continues to hold 20th place. Vinyl chloride production also grew 10% in 1991 to 11.7 billion lb, and occupies the same position (17th) on the list in 1991 as in 1990.

None of the organic chemicals registered double-digit declines in production in 1991. However, the organic chemical registering the biggest drop last year was acetone, down 9% to 2.1 billion lb. The decrease moved it to 44th place from 43rd in 1990. Caprolactam output fell 7% to 1.3 billion lb in 1991, slipping the chemical from 49th place in 1990 to 50th in 1991.

For inorganic chemicals, 10 of the 21 on the Top 50 list posted production increases, led by fertilizer materials potash, ammonium nitrate, and phosphoric acid, each with approximately a 3% increase in 1991. Potash production rose to 3.9 billion lb. Its position on the Top 50 in 1991, however, at 33rd was unchanged from the previous year. Ammonium nitrate production rose to 14.6 billion lb and output of phosphoric acid increased to 24.7 billion lb. Neither advanced on the list—ammonium nitrate remained in 14th place, and phosphoric acid remained seventh.

Three inorganic chemicals had production increases of around 2%: sodium silicate, sodium carbonate, and titanium dioxide. Sodium silicate output increased to 1.8 billion lb and stayed in 45th place in 1991. Sodium carbonate production rose to 20.5 billion lb, giving it the same position, 11th, among the Top 50 in 1991 as it held in 1990. Titanium dioxide production rose to 2.2 billion lb, moving it up to 43rd place in 1991 from 44th the previous year.

Half of the inorganics on the Top 50 list recorded production declines in 1991 compared with 1990. Taking the biggest fall was ammonium sulfate, production of which dropped a little over 12% to 4.5 billion lb. The decline slipped it to 31st on the list, down from 30th in 1990. Two inorganics experienced about a 7% drop in production in 1991: hydrochloric acid and calcium chloride. Hydrochloric acid production was 5.6 billion lb in 1991, but its position on the list, 27th, remained the same as in 1990. Calcium chloride production dropped to 1.3 billion lb in 1991, but it moved up a notch in the listing to 49th place in 1991 from 50th in 1990—only because caprolactam registered a bigger decline. Carbon black and carbon dioxide both saw production declines of 6% in 1990. Output fell to 2.7 billion and 9.8 billion lb, respectively. □

Plastics, synthetic fibers output rise

Overall U.S. production of commercial polymers, including plastics, synthetic fibers, and synthetic rubber, edged up a little over 1% in 1991 compared with 1990. As a result, production reached a new high last year: 62.8 billion lb. However, growth was not so strong as in 1990 when polymer output rose 5% over the previous year and totaled 62 billion lb.

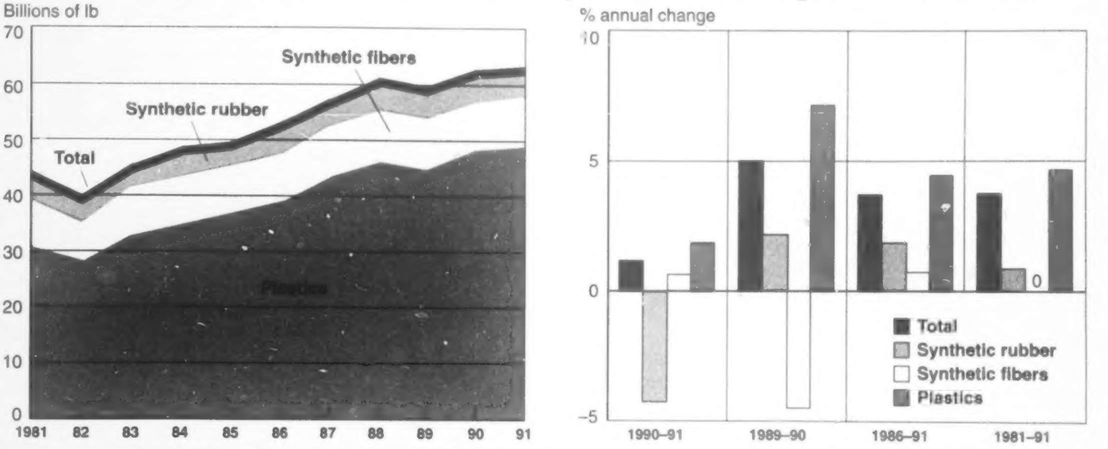
Plastics production, which accounts for more than three quarters of the polymer category's production total, led polymer growth in 1991 with a rise of nearly 2% to 49 billion lb. Synthetic fibers showed a production increase of less than 1% to almost 9 billion lb, and synthetic rubber output declined slightly more than 4% to just under 5 billion lb.

Production of thermoplastic resins grew a bit more than 3% to 43.3 billion lb in 1991 compared with 1990, following nearly 9% growth in 1990. Thermosetting resins production, however, dropped nearly 7% in 1991 to about 6 billion lb. This came after a decline of less than 1% in 1990.

Among the thermoplastics, high-density polyethylene production grew at an annual rate of almost 11% in 1991; it increased only 3% in 1990. Low-density polyethylene turned in the next best performance in 1991, with output up almost 4%, compared with a spectacular 15% rise in 1990. Production of polyvinyl chloride and copolymers rose slightly to just under 1% compared with a 7% increase in 1990. Polypropylene production hardly increased at all in 1991, compared with its 15% increase in 1990. For the second year in a row, polystyrene was the only thermoplastic to register a production decline, down slightly more than 1% in 1991 and nearly 2% in 1990.

In the thermosetting resins category, only unmodified epoxies recorded an increase in production, up more than 6% in 1991 following a 2% decline in 1990. Output of every other thermoset-

Plastics and synthetic fibers output rose, but synthetic rubber output declined in 1991



Total polymer production approached 63 billion lb in 1991

	Billions of lb		Common units				Average annual growth			
	1991	1990	1991	1990	1986	1981	1990–91	1989–90	1986–91	1981–91
PLASTICS (common units = millions of lb)										
Thermosetting resins[b]	**5.94**	**6.36**	**5,943**	**6,364**	**5,834**	**5,010**	**−6.6%**	**−0.6%**	**0.4%**	**1.7%**
Phenol and other tar acid resins	2.66	2.95	2,658	2,946	2,721	2,333	−9.8	2.3	−0.5	1.3
Urea resins	1.48	1.50	1,483	1,496	1,271	1,165	−0.9	1.4	3.1	2.4
Polyesters (unsaturated)	1.08	1.22	1,075	1,221	1,271	997	−12.0	−7.4	−3.3	0.8
Epoxies (unmodified)	0.53	0.50	531	499	398	336	6.4	−2.0	5.9	4.7
Melamine resins	0.20	0.20	196	202	173	179	−3.0	−9.0	2.5	0.9
Thermoplastic resins[b]	**43.26**	**41.91**	**43,255**	**41,912**	**33,569**	**25,671**	**3.2%**	**8.5%**	**5.2%**	**5.4%**
Low-density polyethylene	11.58	11.15	11,580	11,148	8,888	7,693	3.9	15.0	5.4	4.2
PVC and copolymers	9.17	9.10	9,168	9,096	7,256	5,707	0.8	7.3	4.8	4.9
High-density polyethylene	9.22	8.34	9,216	8,337	7,171	4,695	10.5	2.9	5.1	7.0
Polystyrene[a]	4.96	5.02	4,956	5,021	4,442	3,621	−1.3	−1.6	2.2	3.2
Polypropylene	8.34	8.31	8,335	8,310	5,812	3,955	0.3	14.8	7.5	7.7
TOTAL[b]	**49.20**	**48.28**	**49,198**	**48,276**	**39,403**	**30,681**	**1.9%**	**7.2%**	**4.5%**	**4.8%**
SYNTHETIC FIBERS (common units = millions of lb)										
Cellulosics[b]	**0.49**	**0.51**	**486**	**505**	**619**	**770**	**−3.8%**	**−12.9%**	**−4.7%**	**−4.5%**
Rayon[c]	0.27	0.30	273	299	404	509	−8.7	−17.6	−7.5	−6.0
Acetate[d]	0.21	0.21	213	206	215	261	3.4	−5.1	−0.2	−2.0
Noncellulosics[b]	**8.27**	**8.19**	**8,266**	**8,185**	**7,828**	**7,985**	**1.0%**	**−3.9%**	**1.1%**	**0.3%**
Polyester	3.41	3.20	3,410	3,195	3,305	4,176	6.7	−11.1	0.6	−2.0
Nylon[e]	2.54	2.66	2,537	2,662	2,514	2,333	−4.7	−2.8	0.2	0.8
Olefin[f]	1.87	1.82	1,865	1,822	1,393	785	2.4	11.2	6.0	9.0
Acrylic[g]	0.45	0.51	454	506	616	691	−10.3	−6.8	−5.9	−4.1
TOTAL[b]	**8.75**	**8.69**	**8,752**	**8,690**	**8,447**	**8,755**	**0.7%**	**−4.5%**	**0.7%**	**0 %**
SYNTHETIC RUBBER (common units = thousands of metric tons)										
Styrene-butadiene[h]	1.86	1.88	843	853	792	1,032	−1.2	−2.4	1.3	−2.0
Polybutadiene	0.92	0.91	415	412	336	342	0.7	0.2	4.3	2.0
Ethylene-propylene	0.51	0.59	232	266	230	178	−12.8	2.3	0.2	2.7
Nitrile	0.13	0.12	57	56	59	66	1.8	−18.8	−0.7	−1.5
Other[i]	1.47	1.60	668	725	596	404	−7.9	11.9	2.3	5.2
TOTAL[b]	**4.88**	**5.10**	**2,215**	**2,312**	**2,013**	**2,022**	**−4.2%**	**2.2%**	**1.9%**	**0.9%**
GRAND TOTAL	62.83	62.06					1.2%	5.0%	3.7%	3.7%

a No longer includes acrylonitrile-butadiene-styrene, or styrene acrylonitrile resins; historical data are restated. **b** Totals are for those products listed and may not add because of rounding. **c** Includes acetate tow beginning with 1985. **d** Includes diacetate and triacetate yarn, but does not include cigarette tow. Beginning with 1985, includes rayon yarn. **e** Excludes aramid after 1982. **f** Includes olefin film, olefin fiber, spun-bonded polypropylene, and vinyon. **g** Includes modacrylic. **h** Includes high-styrene latex. **i** Beginning with 1985, includes neoprene; historical data are restated. Also includes butyl; polyisoprene; chlorosulfonated polyethylene; polyisobutylene; and acrylo, fluoro, and silicone elastomers. **Sources:** Society of the Plastics Industry, Fiber Economics Bureau, Rubber Manufacturers Association, International Institute of Synthetic Rubber Producers

ting resin—unsaturated polyesters, phenol and other tar acid resins, urea resins, and melamine resins—fell in 1991. They were down 12%, 10%, 1%, and 3%, respectively. In 1990, unsaturated polyester production declined 7%, phenol and other tar acid resins increased 2%, urea resins rose 1%, and melamine resins fell 9%.

Synthetic fibers output made a marginal recovery in 1991 from 1990, reaching 8.75 billion lb. Synthetic fibers registered an almost 1% production rise, shaking off the severe impact the recession had in 1990 when their production dropped 5%. Production of cellulosic fibers continued to slip in 1991, but the nearly 4% decline for the group was not so severe as the almost 13% drop the previous year. Noncellulosics production rose 1%, and polyester led the group with a nearly 7% production rise in 1991 following a 11% drop in 1990.

Production of synthetic rubber decreased 4% to less than 5 billion lb in 1991 compared with 1990, according to the International Institute of Synthetic Rubber Producers (IISRP), Houston. Synthetic rubber data from 1989 and prior years came from the Rubber Manufacturers Association (RMA), Washington, D.C. RMA discontinued its annual report of synthetic rubber production in 1990. An RMA spokesman says the government discontinued its report of synthetic rubber production, and without it RMA has no reliable source against which to check its own data. Only IISRP felt confident enough to release U.S. production data gleaned from its own membership survey.

According to IISRP data, nitrile rubber and polybutadiene were the only synthetic rubbers to show any growth last year, with nitrile rubber output up almost 2% and polybutadiene up less than 1%. All others registered declines in production, with output of ethylene-propylene falling the most, 13%, in 1991 compared with 1990. Production of a group of miscellaneous polymers, including neoprene, butyl, and polyisoprene declined nearly 8% in 1991.

Marc Reisch

SPECIAL REPORT

CHEMICAL INDUSTRY OF THE FORMER U.S.S.R.

Jay K. Mitchell, PlanEcon Inc.

The chemical industry of the former Soviet Union is one of the largest in the world, producing more potash, chemical fertilizers, synthetic rubber, and ammonia than any other country in recent years. At the same time, this is one of the most backward and inefficient chemical industries among industrialized countries, producing mainly unsophisticated bulk products while having to import a large array of downstream products not produced in sufficient quantity or quality domestically.

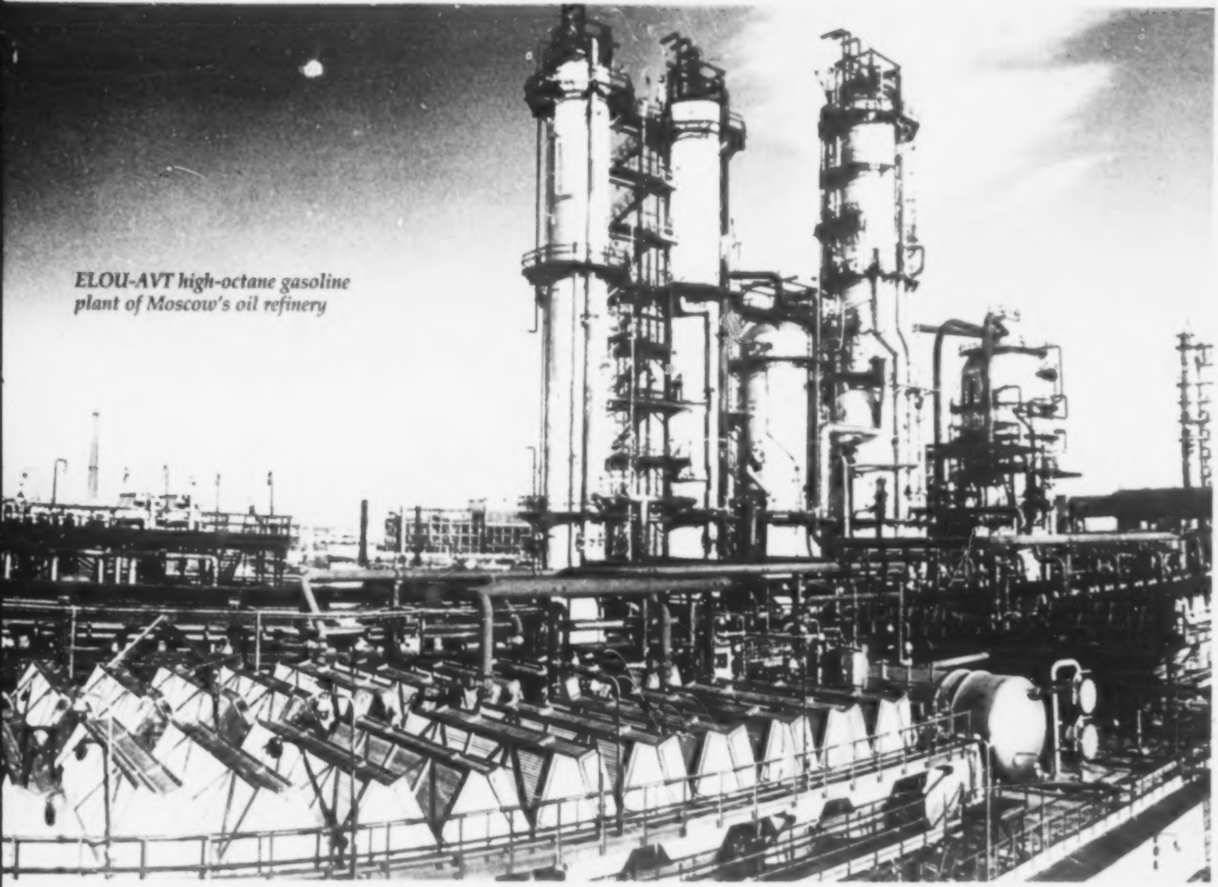
Now, that chemical industry, like the country itself, is splitting into several new entities. Traditional relationships among factories in different republics (now becoming separate countries) have been strained or even totally cut off. The Novomoskovsk detergent factory, for example, one of Russia's largest and most modern detergent producers, located just outside Moscow, has been at a standstill for nearly a year owing to lack of feedstocks, which traditionally came from Kazakhstan. At the same time, each republic is faced with the difficult prospect of reforming and restructuring its economy—and chemical industry—at a time of economic chaos, hard-currency shortages, and growing domestic unrest in many regions.

Clearly the 1990s will be a period of difficult transition. What this transition period will look like, how fast restructuring will take place in the chemical industry, what the industry will look like in the year 2000, how the future prospects differ from republic to republic, and what business opportunities will emerge for Western chemical firms in coming years are some of the crucial issues to examine to understand what the immense changes mean for the chemical industry of the West in coming years.

Chemical industry in crisis

Like the entire economy of the former Soviet Union, the chemical industry finds itself in a recession so deep that it makes the current U.S. recession appear very minor in comparison. Only in the Great Depression of the 1930s have Western economies had any comparable experience. In 1991, the gross national product (GNP) of the former U.S.S.R. was down an estimated 15% from the previous year, industrial output fell nearly 10%, and gross output of chemicals dropped more than 10%. The rate of decline in all three cases accelerated over the course of last year, so that by the end of 1991 the GNP was declining at an annual rate of 20% or more. This year, the economies of the former Soviet republics are likely to experience even sharper declines in aggregate output, especially in those republics, such as Russia, that appear poised to begin radical economic restructuring.

The most important immediate problem for the chemical industry is declining production. Although the estimated 10% drop in gross output of chemicals by the former Soviet Union in 1991 was by far the largest drop in recent decades, it was merely the culmination of a gradual and steady slide.



ELOU-AVT high-octane gasoline plant of Moscow's oil refinery

Photo by TASS SOVFOTO

The average annual rate of growth of Soviet chemical output was a very impressive 10.5% during 1971–75; it subsequently fell to 5.7% during 1976–80, 4.9% during 1981–85, and only 2.8% during 1986–90. In 1990, Soviet chemical output fell a slight 0.9%. Such a massive deterioration over the past two decades has no equivalent in the West, although many East European countries have suffered similar or even greater output declines in recent years.

The deterioration in Soviet chemical performance is clearly reflected in declining production of many major chemical products. Between 1986 and 1990, output of the following chemicals either stagnated or declined: soda ash (3.5% average annual decline); fertilizers (down 2.3%); white pigments (down 2.2%); caustic soda (down 2.0%); ammonia (down 1.7%); benzene (down 0.7%); sulfuric acid (down 0.5%); chemical fibers, methanol, and synthetic rubber (all virtually unchanged); dyes, tires, and plastics (less than 1% average annual growth); and paints (only 1.4% average annual growth). Thus, even those sectors in which the Soviets were leading world producers, such as fertilizers and synthetic rubber, suffered from declining or stagnant output in the late 1980s.

Another major problem of the former Soviet chemical industry is its relatively unsophisticated output. In a period when the worldwide chemical industry is increasingly specializing in niche products, the Soviet portion of that industry has remained largely based on bulk products. In 1990, for example, nearly half (44%) of total Soviet chemical output consisted of bulk inorganic and organic products, including fertilizers. Downstream chemical sectors, such as pharmaceuticals, paints, detergents, and other small-batch chemicals, are highly undeveloped in the former U.S.S.R. As an illustration, pharmaceuticals, soaps, detergents, perfumes, and cosmetics accounted for only about 12% of total Soviet chemical production in 1990, about half of their 24% share of West European chemical output.

Within virtually every chemical sector, the former Soviets

About the cover

The Nizhnekamsk Petrochemical Combine, shown on the cover, is located in the Volga region of Russia and is the second largest chemical complex in that republic. Nizhnekamsk is Russia's largest producer of ethylene (with capacity of 450,000 tons per year) and also produces propylene, benzene, butadiene, ethylbenzene, ethylene glycol, and other petrochemicals. Most of these units date from the 1970s. The Nizhnekamsk complex is also notable because it was one of the first Soviet chemical firms to successfully start up new production capacity under a joint venture with a Western firm: 60,000 tons per year of ethylene glycol capacity came on stream in 1990 as part of a joint venture with MRH of Germany. There is also an oil refinery at Nizhnekamsk that began operating in 1979.

usually produce older, obsolete products: 40% of their plastics output still consists of thermosets, more than one third of chemical fiber output is in cellulosics, oil-based paints still account for more than one third of paint production whereas output of water-based paints remains very small, and general-purpose rubbers still account for more than 80% of synthetic rubber output.

This unsophisticated balance of chemical products has been reflected in Soviet chemical trade in recent years. About two thirds of Soviet chemical exports in 1990 consisted of bulk organic and inorganic chemicals, including fertilizers and chemical raw materials. Moreover, the fraction of chemical exports coming from these categories increased during the 1980s, as the Soviets sought to export almost anything that could earn them much-needed hard currency. This rush to export, and the resulting record export levels for many bulk chemicals, in fact, brought the Soviets several accusations of dumping such products as urea, permanganates, and isobutyl alcohol on world markets.

Imports of downstream products such as paints, dyes, pharmaceuticals, soaps, detergents, and cosmetics accounted for nearly two thirds of total Soviet chemical imports in 1990, up from a 40% share in 1980. Overall, the U.S.S.R. was a large net importer of chemicals during the 1980s, with the deficit rising from about $1 billion in 1980 to a peak of $2.4 billion in 1989. Even these rising chemical imports, however, many of which were chemical intermediates imported to supply the domestic chemical industry, could not stop the slowdown in the growth of the Soviet chemical industry in the 1980s.

A major reason for this disappointing performance has been lack of adequate investment in chemicals by the government in recent years. Between 1980 and 1990, investment in the Soviet chemical industry fell 13% in constant-value terms, even though investment in total industry grew 57% over the same period. Thus, the share of chemicals in total Soviet industrial investment fell from 8.4% in 1980 to 4.7% in 1990. Investment in chemicals was sacrificed during the 1980s to free up resources for machine building and energy production, which saw their combined share in industrial investment rise to 62% in 1990.

The quality of chemical investment also declined considerably over the decade. During the early and mid-1980s, a serious attempt was made to move away from purchasing Western equipment and technology for new Soviet production facilities and to rely instead on suppliers in the U.S.S.R. or Eastern Europe. The result of this attempt was to slow what was already a slow pace of bringing new plants on stream and up to full operating capacity. Declining investment resources were channeled into a few priority sectors, which included plastics and certain bulk inorganic and organic chemicals for export. Consequently, other sectors—notably chemical fibers, paints, dyes, pharmaceuticals, and synthetic rubber—suffered from gross underinvestment during the 1980s.

A second major factor in the deterioration of the Soviet chemical industry has been the nature of the industry itself. On average, Soviet chemical plants are much larger than those in the West, employing thousands of workers. The largest chemical plant in the former U.S.S.R., the Mogilev Chemical Fiber Production Association in Belarus, employs more than 20,000 people. Fifteen chemical plants in the former U.S.S.R. each have more than 10,000 workers, and 79 plants (47 of which are in Russia alone) each employ more than 5000 workers.

But more workers do not necessarily mean higher output. Average worker productivity in the Soviet chemical industry in the late 1980s was only one third that of the U.S. and a mere one fourth that of the former West Germany. Thus, although the former Soviet and U.S. chemical industries employ almost the same number of workers (about 2 million in both cases), the total value of U.S. chemical output each year has been about three times that of the U.S.S.R. Part of this difference comes about because Soviet chemical complexes, like other industrial facilities in the former U.S.S.R., were often responsible for a whole range of functions not considered part of factory work in the West. These included providing employees with food, housing, schooling, and vacations. This practice is slowly changing, but will not be eliminated overnight.

Past Stalinist economic policies held that large factories would help industrialize the country faster and lead to increased economies of scale. The legacy of these policies is a large number of massive complexes in desperate need of restructuring. In many cases, existing complexes must be split into several smaller units before any investor—domestic or foreign—is likely to be interested in them.

Another problem is the need to convert chemical plants formerly in the defense sector to civilian use. Although this problem is more severe in other sectors of industry, such as machinery, it is still significant for chemicals. Some chemical plants produced their entire output for the military; others, though also producing for other uses, still counted on the military to purchase much of their production. Now, as demand by the military collapses in most of the former U.S.S.R., these chemical facilities find that a major market for their output has been eliminated almost overnight. They must find new markets for existing production (an easier task in the case of chemicals than for most machinery), change their output profile to attract buyers for their products, or face going out of business.

Reforms appear imminent

The major positive accomplishment of the failed August 1991 coup in the Soviet Union was rapid dismemberment of the old economic system. Mikhail Gorbachev, although a true reformer in the spheres of domestic politics and foreign policy, was a dismal failure on the economic front. Despite his promises to reform the U.S.S.R.'s economy and several real opportunities to do so, the former Soviet leader hesitated every time it came to actually implementing reforms. Essentially, Gorbachev managed to dismantle much of the old centrally administered command economy without providing a viable replacement, such as a market system. The result was disaster for both the Soviet economy and Gorbachev's own political career.

Now that authority has passed to the individual republics, the outlook for economic reform is much improved. The Baltics are moving ahead rapidly to introduce a market system. And many republics, including the second largest, Ukraine, intend to introduce their own currencies. Russia, led by Boris Yeltsin, is also attempting a rapid reform of its economy, having raised (but not totally decontrolled) prices in early January.

The key to reform in many of the former Soviet republics is what happens in Russia. If Russia proceeds with its already-declared plans to charge other republics world market prices for the raw materials it supplies to them (including oil and gas that serve as feedstocks for petrochemicals), then those republics will be strongly compelled to free prices or face rising subsidies. On the other hand, if Russian reform efforts stall or become bogged down by popular opposition (such as that witnessed following the January price rises), then it will be more difficult for the other republics to follow a fast track on reform. The huge Russian market of nearly 150 million consumers has been the most important one for nearly every former Soviet republic, and it is likely to remain so for the near future.

The economic reform process will be difficult throughout the former Soviet Union. As the East European economies have shown, economic restructuring leads to short-term production declines, rather than increases, as older, less efficient production units are closed down permanently or temporarily for revamping. In the case of chemicals, decades of inadequate and poorly utilized investment have rendered entire sectors of production—including paints and chemical fibers—uncompetitive in world markets. Restructuring these sectors will be especially painful. For other chemical sectors, economic restructuring will lead to a fall in short-term demand, which will hurt output. In particular, demand for bulk fertilizers will decline because of price liberalization, and chemical fiber demand is likely to drop as well if textiles become one of the industrial sectors hardest hit by the recession, as happened in Eastern Europe.

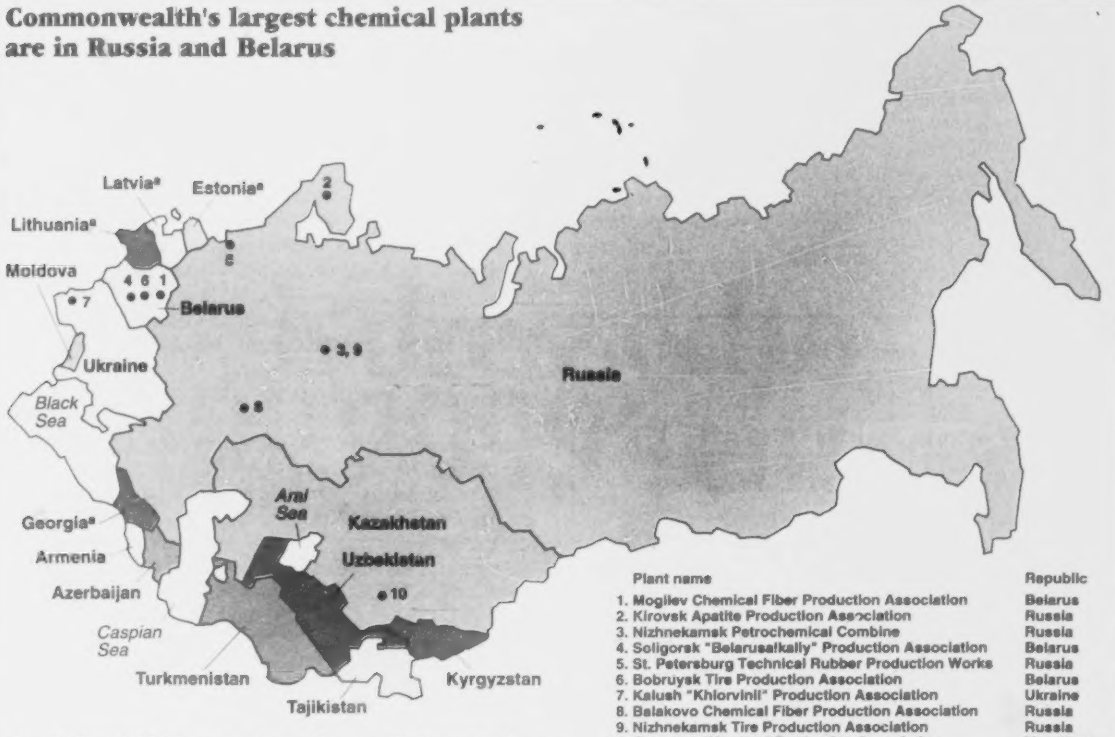
Despite these drawbacks, economic reforms are likely to proceed in the majority of the former Soviet republics, including all-important Russia, if only because there is no viable alternative. The failed August coup drove the nails into the coffin of the old economic system. And the reform process will be aided by the West. Assistance from both Western governments and multilateral institutions like the World Bank and International Monetary Fund will help to keep the reforms on track.

However, it likely will be several years before these reforms have a positive impact on the chemical industry. Declines in overall chemical output will continue through the mid-1990s. For example, I predict chemical output of the former U.S.S.R. in 1995 will be a full 16% below the 1990 level because of the closure of many factories. Full-fledged recovery in chemical output is not really feasible, given the depth of restructuring required in Russia and other reform-minded republics, before the late 1990s. Thus, the recession in the former Soviet chemical industry will be a long one.

Profile for 2000

Once economic recovery begins in the late 1990s, it likely will gain momentum swiftly. For chemicals, consumer-oriented product sectors such as plastics, organic intermediates, pharmaceuticals, soaps, and detergents will drive the recovery. Just as these sectors were largely neglected in past

Commonwealth's largest chemical plants are in Russia and Belarus



	Plant name	Republic
1.	Mogilev Chemical Fiber Production Association	Belarus
2.	Kirovsk Apatite Production Association	Russia
3.	Nizhnekamsk Petrochemical Combine	Russia
4.	Soligorsk "Belarusalkaliy" Production Association	Belarus
5.	St. Petersburg Technical Rubber Production Works	Russia
6.	Bobruysk Tire Production Association	Belarus
7.	Kalush "Khlorvinil" Production Association	Ukraine
8.	Balakovo Chemical Fiber Production Association	Russia
9.	Nizhnekamsk Tire Production Association	Russia
10.	Zhanatas "Karatau" Production Association	Kazakhstan

a Part of the former U.S.S.R., but not part of the new Commonwealth of Independent States.

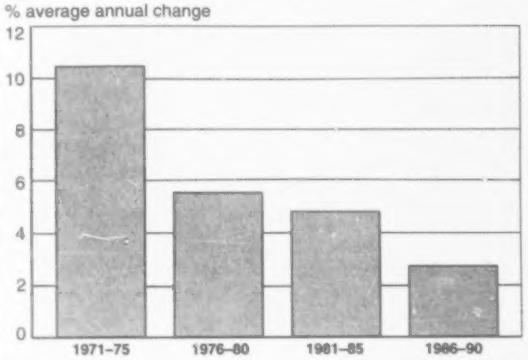
Soviet industrial strategies, the new market environment will create conditions for them to flourish. Western investment could become particularly significant in all these sectors.

By the year 2000, the combined chemical industries of the former Soviet republics will be smaller and more productive than the Soviet chemical industry was. In particular, less phosphorus, sulfuric acid, calcium carbide, mineral fertilizers, chemical fibers, and paints will be produced, and production of numerous other chemicals will stagnate or rise only modestly. This slowdown will be brought on by the large-scale shutdown of older plants that are obsolete, inefficient, polluting, or all three. Chemical employment also will shrink during the 1990s as restructuring and modernization make at least one third of current chemical jobs redundant. Thus, in 2000, the chemical industry of the post-Soviet republics will employ no more than 1.2 million to 1.3 million workers, compared with the current 1.8 million to 1.9 million.

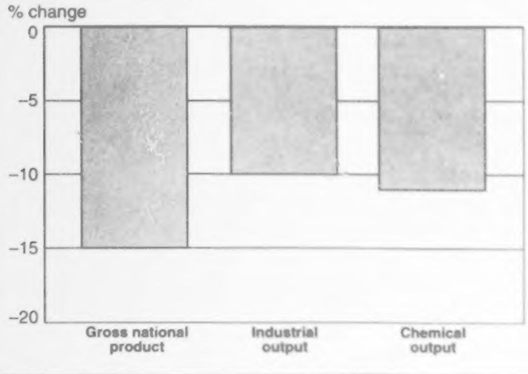
But although production and employment in chemicals will contract, the value of chemicals produced will actually rise. Whereas total Soviet output of chemicals and petrochemicals was estimated by PlanEcon in 1990 at $85 billion (at world market prices), by 2000 output could be worth $100 billion or more. Much of the existing capacity that must be shut down in coming years represents units that produce lower quality and lower value products and that probably should have been closed long ago. Specifically, chemical fiber capacity to be closed in coming years will consist largely of cellulosic fiber units, which are inefficient and heavily polluting. Fertilizer units likely to be decommissioned include bulk single-nutrient products, which have added to soil and water pollution problems in recent decades, rather than high-nutrient complex and compound substances. Thus, the loss to the value of chemical output by the former Soviet republics from these plant closures is not so great as it might seem at first glance.

Moreover, a wave of modernization during the second half of the 1990s will result in building new units that will add substantial capacity in higher value-added products, such as small-batch products, consumer chemicals, and plastics. In small-batch chemicals, new capacity to make water-based paints, synthetic dyes, gasoline and fuel additives, plastics additives, rubber chemicals, environmentally friendly plant pesticides and microbiological products is expected to be built during the late 1990s.

Slower growth for Soviet chemical industry began in late 1970s



U.S.S.R.'s final year (1991) was a bad one for the economy



In all of these areas, the current capacity in most republics is too small and the likely future market too great to avoid building new units. For example, environmental concerns will probably compel the republics to begin converting to unleaded gasoline during the 1990s. At the same time, more private cars will raise demand for various gasoline additives and car-care products. Some of this demand could be met through imports, but the very large potential markets in Russia, Ukraine, and other republics will almost certainly lead to domestic production of many of these products, including some production with the assistance of Western investors. Similarly, the need for manufactured goods from Russia, Ukraine, Kazakhstan, and other republics to compete on world markets will require much improved paints. In the near-term, paint imports will rise, but eventually domestic production also will rise to meet part of the demand increase.

Recent extremely high levels of consumer chemical imports point to attractive future production opportunities. The U.S.S.R. imported an average of more than $1 billion annually of pharmaceuticals, soaps, and detergents from the West during 1988–90, a period of extremely tight hard-currency restrictions. This unprecedented high level occurred because of grave domestic shortages, and points to a huge unsatisfied demand there. Thus, just as has been occurring in Eastern Europe, consumer chemicals could become one of the most popular chemical sectors for Western investment. In particular, the massive size of the Russian market (nearly 150 million consumers) as well as Ukraine (more than 50 million consumers) provides potential sales opportunities unmatched by any East European country and superior to virtually any other emerging market today. Already, Ukraine has been the target of a number of small-scale investments involving consumer chemicals, suggesting that activity could take off there even faster than in Russia.

Current low per capita levels of plastics production and consumption point to immense growth potential. At present, per capita plastics consumption in all the former Soviet republics is only about 20 kg per year, about one fifth of the U.S. level. Modernization and economic restructuring will raise plastics demand during the 1990s, as plastics replace such materials as wood and metals in applications that include construction materials and packaging. Plastics production capacity is already being expanded through a number of ventures involving Western capital, including one in which the U.S. chemical firm Huntsman (Salt Lake City, Utah) plans to build a polystyrene plant in Ukraine, another in which Germany's Linde will modernize and expand an existing polyethylene facility at Novokuybyshevsk in Russia, and the huge Wespec venture with the U.S. firm Combustion Engineering that will build sizable polypropylene capacity at Tobolsk in Russia.

Despite these expected gains, however, the chemical industry in the former Soviet republics in 2000 will still be based mainly on bulk chemicals. Output of basic inorganic chemicals, such as caustic soda and soda ash; organic chemicals, such as ethylene and methanol; and mineral fertilizers, such as urea, will still predominate. Such continued emphasis on bulk products is not necessarily bad, given the former U.S.S.R.'s vast resources of oil and gas for petrochemical synthesis and of chemical raw materials for making fertilizers and other bulk inorganic chemicals. Indeed, the comparative advantage of the chemical industries of Russia, Kazakhstan, and certain other former Soviet republics will remain in upstream output.

And the market for many of these bulk chemicals could be quite favorable in the late 1990s and beyond. With Eastern Europe expected to sharply curtail output of many bulk chemicals, including single-nutrient fertilizers, because of much higher costs of oil and gas feedstocks as well as other raw materials, Russia and other former Soviet republics could find growing demand for their basic chemicals there. Western Europe, too, may be a good market for certain of Russia's traditional bulk exports. For example, world methanol supplies are expected to tighten in coming years, making Russian exports potentially quite lucrative. Soviet methanol exports averaged nearly 1 million metric tons per year in the late 1980s, most of which came from Russia. This made the U.S.S.R. the leading world exporter of methanol during the past decade.

Production growth slowed in late 1980s for most chemical product areas in former U.S.S.R.

Thousands of tons, except as noted	Production 1980	1985	1990	% average annual change 1981–90	1981–85	1986–90
BASIC INORGANIC CHEMICALS						
Ammonia, synthetic	16,732	22,167	22,208	2.9%	5.8%	0 %
Caustic soda	2,755	3,056	2,973	0.8	2.1	−0.5
Sulfuric acid	23,033	26,037	27,300	1.7	2.5	1.0
Soda ash	4,661	4,916	4,359	−0.7	1.1	−2.4
AGRICULTURAL CHEMICALS						
Mineral fertilizers, 100% nutrient	24,767	33,194	31,676	2.5	6.0	−0.9
Nitrogen, 100% N	10,241	14,223	13,208	2.6	6.8	−1.5
Phosphate, 100% P_2O_5	6,455	8,596	9,431	3.9	5.9	1.9
Potassium, 100% K_2O	8,071	10,375	9,037	1.1	5.2	−2.7
Plant pesticides, 100% active	282	6,137	205	−3.1	85.2	−49.3
PLASTICS AND SYNTHETIC RESINS	3,637	5,019	5,536	4.3	6.7	2.0
Polyethylene	278	559	642	8.7	15.0	2.8
Polypropylene	32	93	127	14.8	24.0	6.3
Polystyrene	247	466	515	7.6	13.6	2.0
Polyvinyl chloride	398	455	606	4.3	2.7	5.9
CHEMICAL FIBERS	1,176	1,394	1,477	2.3	3.5	1.2
Artificial fibers, cellulosics	606	605	522	−1.5	0	−2.9
Synthetic fibers, noncellulosics	570	789	955	5.3	6.7	3.9
SMALL-BATCH CHEMICALS						
Paints and varnishes	2,883	3,315	3,543	2.1	2.8	1.3
Dyes, synthetic (tons)	81,033	73,355	83,959	0.4	−2.0	2.7
Detergents, synthetic	1,012	1,150	1,503	4.0	2.6	5.5
Soap, 60% basis	1,045	976	1,137	0.9	−1.3	3.1
BASIC ORGANIC SYNTHESIS PRODUCTS						
Olefins						
Ethylene	1,773	2,667	3,065	5.6	8.5	2.8
Propylene	824	1,177	1,366	5.2	7.4	3.0
Aromatics						
Benzene	1,644	1,971	2,080	2.4	3.7	1.1
Toluene	1,202	1,023	1,027	−1.6	−3.2	0.1
Xylenes	459	937	943	7.5	15.3	0.1
Alcohols						
Butanols	205	300	343	5.3	7.9	2.7
Ethanol	306	276	229	−2.9	−2.0	−3.7
Methanol	1,900	2,850	3,233	5.5	8.4	2.6
SYNTHETIC RUBBER	2,050	2,125	2,350	1.4	0.7	2.0

Source: December 1991 PlanEcon *Soviet Chemical Review*

Prospects differ for republics

The republics of the former Soviet Union have vastly different chemical industries, ranging from Russia's huge industry, which produced chemicals and petrochemicals with an estimated value of $55 billion in 1990, to Moldova's, which produced less than $200 million the same year. Areas of emphasis also differ, from bulk petrochemicals in Russia and Kazakhstan to agricultural chemicals in Ukraine and

Moldova, chemical fibers in Belarus, and downstream products in the Baltics. Thus, any discussion of the future for these republics' chemical industry must consider prospects for individual republics.

Russia. The Russian chemical industry, with an estimated $55 billion worth of chemical and petrochemical production in 1990, is roughly the size of Italy's chemical industry. But Russia has more than twice the population of Italy, making its per capita chemical production less than that of many East European countries, including Czechoslovakia and Hungary. Its chemical industry includes more than 600 plants employing nearly 1 million workers (977,000 in 1989). Russia's real strength as a chemical producer lies in the republic's vast natural resources. Abundant oil and gas reserves make it a huge petrochemical producer, and vast deposits of chemical raw materials, such as sulfur and phosphorus, feed a massive inorganics and fertilizer sector. Russia produces just under two thirds of the total value of chemicals from the former U.S.S.R., and its share in production of certain bulk products is even higher: caustic soda, soda ash, and polyvinyl chloride (about 75%); polypropylene, xylenes, and methanol (more than 80%); and acetone, phenol, synthetic rubber, and high-density polyethylene (more than 90%).

Russia's small-batch and consumer-oriented chemical production is its major weakness. Production facilities for paints and dyes are antiquated, and at least half of existing capacity should be closed down. Despite recent attempts to boost the quality and quantity of output of pharmaceuticals, soaps, and detergents, the Russian market is one of the most undersupplied with these products.

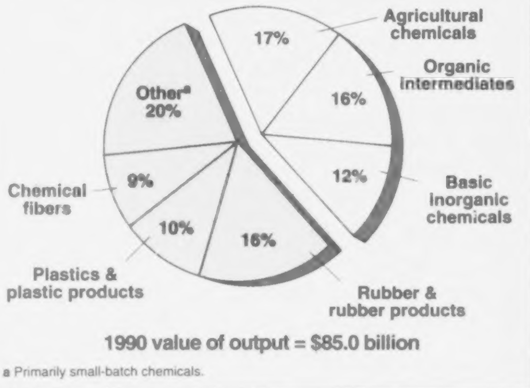
Chemical fibers are another weak aspect of Russian chemical production. Although Russia accounts for nearly two thirds of total cellulosic fiber production in the former Soviet republics, its share in more modern synthetic fibers is less than two fifths. In particular, Russia produces very little polyester, acrylic, or polypropylene fiber.

Russia's chemical industry has very good prospects for the 1990s and beyond, thanks to foreign investment. Investment will begin as a ripple in the next year or two, but by the end of the decade, it is expected to have become a tidal wave. Russia's chemical industry is one of the few in Europe with ready access to a wide range of relatively cheap, abundant, and domestically produced chemical feedstocks. Russia's enormous market for consumer chemicals—it has more than double the population of the U.K., France, or Italy—is likely to attract foreign investment in areas such as soaps, detergents, and pharmaceuticals. And there's good potential for growth in other spheres as well, including plastics, noncellulosic fibers, and paints.

Russia's chemical industry is not without challenges, however, which include an underdeveloped and overtaxed transport and telecommunications network. These problems are especially acute in remote areas, such as Siberia, where a large portion of foreign investment in chemicals this decade is likely to be headed. The country's immense potential as a chemical producer and exporter, however, ensures sizable foreign investment that will help to upgrade and modernize existing plants as well as build entirely new facilities.

Ukraine. The second largest republic of the former Soviet Union is also its second largest chemical producer, with chemical production in 1990 valued at an estimated $15 billion. In per capita chemical output, though, Ukraine not only lags behind most Western countries, but also the republics of Russia and Belarus. Over the past 20 years, when new chemical and petrochemical complexes were being built in Russia, Belarus, and Kazakhstan, relatively little new capacity has been commissioned in Ukraine.

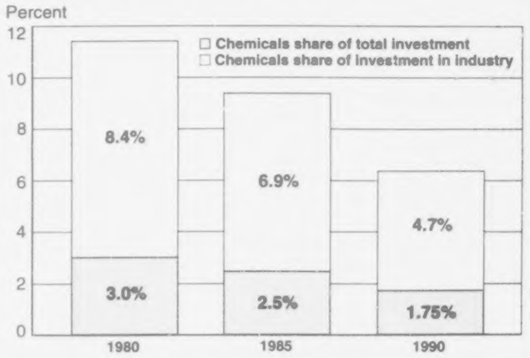
Nearly half of 1990 Soviet chemical output was in agrochemicals, organics, inorganics



In contrast to Russia and Kazakhstan, Ukraine does not have the abundant oil and gas reserves needed to drive a vibrant petrochemical industry. Rather, its petrochemical sector is based largely on coke chemicals. This capacity is outmoded and many units will be shut down in coming years. Ukrainian petrochemical producers face the unhappy prospect of paying several times more for feedstocks once the prices Ukraine pays for Russian and Kazakh oil and gas rise to world market levels.

The Ukrainian chemical industry consists of 208 plants employing some 295,000 workers. As in Russia, production is largely in bulk, rather than downstream, products. Unlike

Chemical industry has been losing its share of Soviet industrial investment



Russia, however, Ukraine's chemical industry does not have easy access to cheap and abundant raw materials for inorganic and organic chemical synthesis. Thus, Ukrainian chemical managers will need to shift at least a portion of production further downstream in order to remain profitable. The country's current production profile suggests just how difficult this shift might be. Ukraine accounted for only 14% of total Soviet plastics output in 1989, and its share of chemical fiber production was only 12%.

Recently, however, Western investors have expressed interest in Ukrainian consumer chemicals and plant pesticides, and these two spheres hold promise for future development. Consumer chemicals look promising because of Ukraine's large and geographically concentrated market and the republic's closer proximity to Europe than Russia's market. Plant pesticides invite Western investors because Ukraine is one of the most productive agricultural regions of the former Soviet republics. It is also a major producer of dyes, accounting for more than one third of Soviet production in 1989 and having some of the more modern dye factories in the republics. Almost all of the former Soviet Union's titanium dioxide was produced in Ukraine. Thus, the Ukrainian chemical industry has serious challenges ahead, but shows some potential to move production further downstream.

Belarus. Although Belarus (formerly Byelorussia) is only the fifth largest former Soviet republic in terms of population, it is the third largest chemical producer. This republic of 10 million people produced an estimated $5 billion in chemicals in 1990. Thus, Belarus produced an estimated $490 of chemicals per capita in 1990, making it by far the most productive of the former Soviet republics by this measure.

Belarus' chemical industry enjoys certain other advantages as well. It is among the most modern of all the republics, producing plastics and plastics products, synthetic fibers, organic intermediates for fiber manufacture, and potassium fertilizers. Belarus accounted for more than 80% of Soviet polyester fiber output in the late 1980s, and its share of acrylic fiber production was more than 50%. Also, Belarus' 47 chemical plants, which employ about 100,000 people, earned 50% greater profits in 1990 than the average Soviet chemical firm.

Still, the Belarus chemical industry has several weaknesses. Most important, it is highly dependent on imported oil and gas feedstocks, which, in the past, came from Russia. Russia now appears poised to charge Belarus and the other former Soviet republics world market prices for its exports. Such a change would hit the industry hard, as it has the chemical industries of many East European countries during the past two years.

Paint output in Belarus is minimal, and dye production is practically nonexistent. Output of plant pesticides is also minimal, even though agriculture remains an important sector of the Belarus economy. Belarus' share of both detergents and pharmaceuticals was below its share in total Soviet chemical output in 1990. These consumer chemicals aren't likely to attract Western investors, given the relatively small size of the domestic market, compared with those of neighboring Russia, Ukraine, and even Poland.

Perhaps Belarus' greatest disadvantage, however, is that this republic is one of the lesser-known in the West. The recent decision to place the capital of the newly formed Commonwealth of Independent States in Minsk has helped to put Belarus "on the map," but it will take aggressive efforts from the republic's leaders to attract sizable Western investment to what is one of the most modern chemical industries in the former U.S.S.R.

Kazakhstan. Although it has a larger population than Belarus, Kazakhstan has barely half the chemical output (valued at an estimated $2.6 billion in 1990). Kazakhstan has 39 chemical plants employing a total of about 83,000 people. Like Belarus, Kazakhstan has a relatively modern chemical industry, which began when several plants were evacuated here from Russia during World War II. However, the republic's chemical facilities are relatively unprofitable and very heavy consumers of energy—the average chemical plant in Kazakhstan consumed three times the amount of electricity used by the average Soviet plant in 1990. Energy-intensive products such as inorganic chemicals and bulk fertilizers figure prominently in Kazakhstan's chemical production; other major products include chemical raw materials, rubber, and rubber products.

The future of Kazakhstan's chemical industry lies in petrochemical synthesis and sour-gas recovery of sulfur. Large oil and gas reserves make this republic a natural candidate for petrochemical complexes, and several attempts have been made to build such complexes in recent years with the

Ten largest chemical complexes in former U.S.S.R. each employ more than 11,000 workers

No.	City and complex name	Republic	Number of workers	Major products
1	**Mogilev Chemical Fiber Production Association**	Belarus	20,320	Chemical fibers
2	**Kirovsk Apatite Production Association**	Russia	17,780	Chemical raw materials
3	**Nizhnekamsk Petrochemical Combine**	Russia	16,190	Organic synthesis chemicals
4	**Soligorsk "Belarusalkaliy" Production Association**	Belarus	13,420	Chemical raw materials
5	**St. Petersburg Technical Rubber Production Works**	Russia	13,350	Rubber products
6	**Bobruysk Tire Production Association**	Belarus	13,230	Rubber products (tires)
7	**Kalush "Khlorvinil" Production Association**	Ukraine	13,090	Organic synthesis chemicals
8	**Balakovo Chemical Fiber Production Association**	Russia	12,730	Chemical fibers
9	**Nizhnekamsk Tire Production Association**	Russia	12,040	Rubber products (tires)
10	**Zhanatas "Karatau" Production Association**	Kazakhstan	11,160	Chemical raw materials

help of Western investors, including an ill-fated project at Tenghiz involving Occidental Petroleum and other Western firms. Most of these projects were stalled or even canceled after Western investors became disillusioned by bureaucratic hurdles and logistical problems, which include lack of storage and transport facilities, lack of adequate housing and services for prospective employees, and poor telecommunications services. To attract foreign investment and support large new petrochemical capacity, Kazakhstan needs to build up its infrastructure and transportation facilities.

Perhaps more so than for any other republic, Kazakhstan's future depends on its relations with Russia. A huge number of Russians live in Kazakhstan, and Russian President Yeltsin has already hinted at possible border disputes between the two republics. Further possibility of conflict might come should Kazakhstan decide to compete directly with Russian Siberia for large-scale Western investment in petrochemicals. Given these factors, Kazakhstan's chemical industry is likely to remain relatively undeveloped through the late 1990s. But the potential remains for considerable development after 2000.

Transcaucasus. The three Transcaucasus republics—Armenia, Azerbaijan, and Georgia—are highly unstable politically, and this spells trouble for their chemical industries in coming years. The war between Armenia and Azerbaijan, combined with civil war in Georgia, threaten to make this region into another Lebanon. These republics' chemical industries are fairly small—together, the three produced an estimated $3.1 billion in chemicals in 1990. Output tends to be in bulk chemicals in Azerbaijan, including chlor-alkalies, sulfuric acid, ethylene, propylene, and synthetic rubber. Georgia's output is more downstream-oriented in products such as polypropylene fibers, detergents, paints, and pharmaceuticals. Armenia makes both bulk and downstream products, including nitrogen fertilizers and bulk organic chemicals, but also plastics and plastics products, pharmaceuticals, and rubber and rubber products.

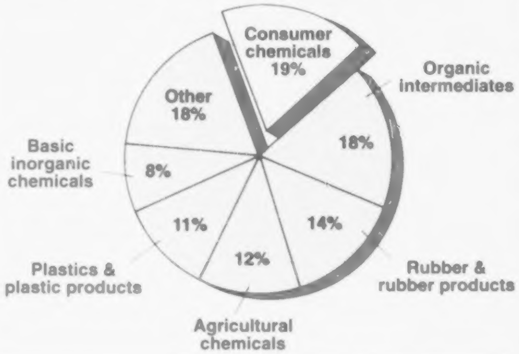
These three republics together have 93 chemical plants, about half of them in Georgia, employing about 66,500 people. Unless a peaceful resolution can be found to both Georgia's bloody civil war and the hostilities between Armenia and Azerbaijan, it will be hard to modernize and upgrade chemical facilities or to attract Western investment.

Mistakes of the past also cloud the future of chemicals in the Transcaucasus. In Armenia, for instance, the highly polluting Nairit rubber facility, located in a suburb of Yerevan, Armenia's capital, has helped to spawn a vocal grass-roots "green" movement that is expected to act as a constraint on future development of chemicals in that republic. Such movements have sprung up all over the former Soviet republics in recent years and have gained growing influence with politicians.

Baltics. The three Baltic republics of Estonia, Latvia, and Lithuania have some of the most downstream-oriented chemical industries in any of the republics. Unlike most of the republics, the Baltic republics have not become members of the Commonwealth of Independent States and are expected to pursue their own path to full economic and political independence.

These three republics, containing only about 8 million people, produced an estimated $2 billion worth of chemicals in 1990. The 46 chemical plants located in the Baltics, employing about 52,000 people, produce mainly plastic products, pharmaceuticals, rubber products, and other consumer-oriented products (such as soaps, detergents, perfumes, and cosmetics). Bulk chemicals produced in the Baltics include inorganic acids (nitric and sulfuric), fertilizers (nitrogen and phosphate), and methanol and calcium carbide (both in Lithuania).

Consumer chemicals will be largest sector of republics' chemical output by 2000



Notably absent from Baltic chemical output are primary plastics, and the secondary processors located there must import polymers either from other former Soviet republics or from abroad. This interdependence has, until now, been imposed on these republics by the central government in Moscow. It is a legacy of the Stalinist economic model, which sought to forcibly integrate the economies of the Baltic republics with that of the remainder of the U.S.S.R. following their annexation in 1940.

The outlook for the chemical industry in the Baltics is mixed. On the one hand, these three republics already produce an impressive array of downstream products, and their chemical facilities are, on average, more modern and efficient than those in other former Soviet republics. But the chemical industry in the Baltics faces several challenges. First, it will be hit particularly hard by the need to pay world market prices for oil and gas feedstocks, since domestic resources are minimal. Lithuania, in particular, has a sizable refinery and petrochemical complex that has depended on cheap Russian oil in the past. Second, the rapid departure of the Baltics from the union has left relations somewhat strained with Russia, which has been a significant market for their chemical output. And third, several plants face closure: The calcium carbide facility at Kaunas in Lithuania and oil-shale-based organic chemical units in Estonia are old, inefficient, and highly polluting.

Central Asia. Although the four remaining republics in Central Asia—Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan (the fifth, Kazakhstan, has been discussed separately)—accounted for more than 10% of the population of the former Soviet Union, their share in Soviet chemical output in 1990 was only 2.4%. This highly undeveloped region has a burgeoning population, but only produced an estimated $2 billion worth of chemicals in 1990. Almost all of this chemical output is in Uzbekistan, with the other three republics having minuscule chemical industries. These four republics have 57 of the most unprofitable chemical plants in the former U.S.S.R., employing about 60,000 people. Located there are several energy-intensive complexes for producing bulk inorganic chemicals and fertilizers, even though these republics have little in the way of domestic energy resources.

This legacy of past inappropriate industrialization policies imposed by a central government in Moscow will not necessarily be solved by independence. Indeed, one unfortunate legacy—environmental degradation caused not only by chemical production but also by faulty irrigation practices and excessive use of fertilizers—will remain for a long time. The outlook for this region's chemical industry is poor, given its unfavorable economic and political prospects and lack of attractive investment prospects for Western investors. And although past economic policies imposed by Moscow were flawed, these republics' chemical industries probably still received more investment resources than they would have been able to pull together had they been independent entities.

Moldova. Tucked in the European portion of the former Soviet Union, tiny Moldova (formerly Moldavia) with just 4 million people has an equally tiny chemical industry. Estimated value of chemical output in 1990 by the republic's 17 plants, employing about 4400 people, was less than $200 million. The major spheres of activity are downstream products—detergents, paints, and pharmaceuticals. But output is too small to be considered impressive. Future prospects for Moldova's chemical industry almost certainly include closer cooperation with neighboring Romania, of which Moldova was a part until it was forcibly annexed by the Soviets during World War II. Closer cooperation with Romania would benefit Moldova's chemical industry, since on its own it has poor prospects for modernization and expansion.

Emerging business opportunities

Despite the tough times ahead for the republics' chemical industries, Western chemical firms will find an increasingly diverse and attractive array of business opportunities during the 1990s. These opportunities include not only the trade and joint-venture activities already being conducted, but also new possibilities—such as mergers with and acquisitions of former Soviet chemical facilities, fully owned Western subsidiaries, and practically the full range of business transactions known in the West.

New horizons also will open up as Western exporters and importers gain direct access to the output of individual facilities, rather than the past practice of working with centralized foreign trade organizations. And individual republics are expected to alter their foreign investment laws in an effort to woo much-needed Western capital. In some instances, republics may find themselves in direct competition with other republics or with certain East European countries for Western investment. Such competition will improve opportunities for Western investors, by providing tax holidays and other favorable concessions. Opportunities in the former Soviet chemical industry in the 1990s will be different, however, in different sectors of the industry.

Although the former Soviet Union was a leading world producer of many basic inorganic chemicals, it was not one of the most modern producers. Thus, many of the existing facilities will not make attractive joint-venture or takeover targets since they embody older technologies. For example, most sulfuric acid plants are obsolete units supplied by Poland more than a decade ago, and chlor-alkali units mainly use old, mercury-cell technology. Some exceptions might include the Kalush "Khlorvinil" Enterprise in the Ukraine, a relatively modern chlor-alkali complex; the Volgograd caustic soda production association in Russia, for which the Japanese are supplying equipment for a caustic soda unit due on stream in 1992; and some newer soda ash and ammonia units at Achinsk, Berezniki, and Togliatti in Russia, Krasnoperekopsk in Ukraine, and Grodno in Belarus. The most attractive opportunities for bulk inorganic chemicals in coming years will be in Russia and Ukraine, given the sizable number of large-scale and somewhat modern producers located there.

The former Soviet Union was also the world's largest fertilizer producer and exporter, but its output consisted mainly of single-nutrient products like urea, ammonium nitrate, and superphosphates. Most of its fertilizer producers are not attractive joint-venture partners or takeover targets because they have old facilities and usually embody less desirable Soviet or East Euro-

Four republics accounted for more than 90% of Soviet chemical output in 1990

	Share of Soviet chemical output, %	Estimated value of chemical output ($ billions)	Share, %	Estimated per capita chemical output (in dollars)	Index (U.S.S.R. average = 100)	Market size (population in millions)	Share, %
Russia	64.7%	$55.0	64.7%	$373.0	127.3	148.5	51.2%
Ukraine	17.8	15.1	17.8	290.0	99.0	51.9	17.9
Belarus	5.8	5.0	5.9	490.0	167.2	10.3	3.6
Transcaucasus (Armenia, Azerbaijan, and Georgia)	3.6	3.1	3.6	197.0	67.2	16.0	5.5
Kazakhstan	3.1	2.6	3.1	157.0	53.6	16.8	5.8
Baltics (Estonia, Latvia, and Lithuania)	2.4	2.0	2.4	252.0	86.0	8.0	2.8
Central Asia (Kirghizia, Tajikistan, Turkmenistan, and Uzbekistan)	2.4	2.0	2.4	61.0	20.8	34.2	11.8
Moldova	0.2	0.2	0.2	39.0	13.3	4.4	1.5
TOTAL U.S.S.R.	100.0%	$85.0	100.0%	$293.0	100.0	290.0	100.0%

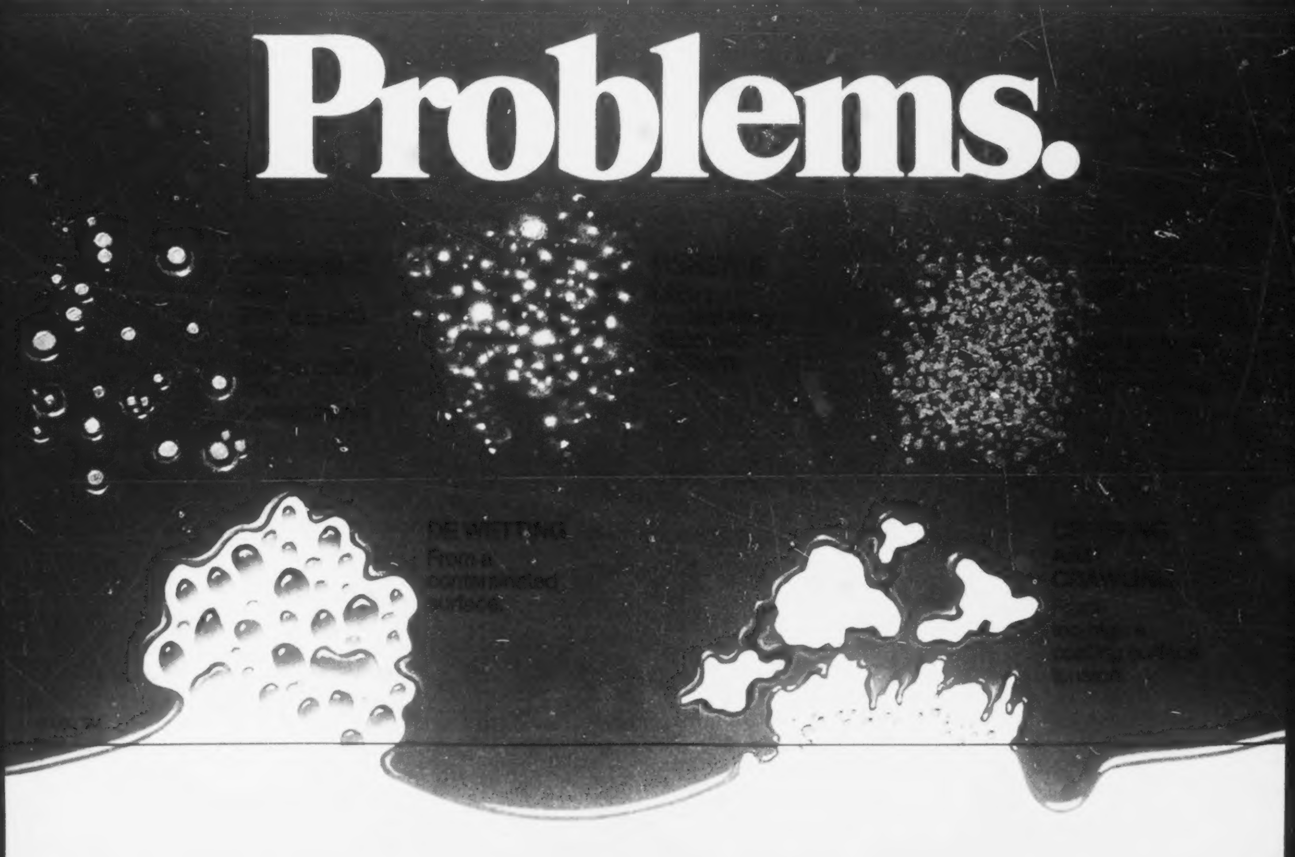
pean technology. Notable exceptions include Togliatti in Russia, one of the world's largest nitrogen fertilizer complexes, with some newer units completed in the late 1970s and 1980s using Western technology; Gorlovka in the Ukraine; Berezniki in Russia; and Kemerovo in Russia, where the Italian engineering firm Tecnimont supplied 500,000 metric-ton-per-year urea units during the 1980s; and Dorogobuzh, Novgorod, and Rossosh in Russia, where the Japanese supplied large nitrogen-phosphorus-potassium units during the 1980s.

The former Soviet republics will be a good market for Western producers of plant pesticides in coming years. A recent joint venture involving such chemicals between the British firm ICI and farms in Ukraine illustrates the possibility for mutual benefit even in the present chaotic economic situation. The venture, basically a barter arrangement, provides for Ukrainian sales of agricultural products in order to purchase agrochemicals and other products from ICI. These chemicals, in turn, likely will help raise Ukrainian agricultural yields. Indeed, Ukraine, with its large agricultural base, would seem a natural candidate for both direct sales of plant pesticides as well as joint ventures in this area.

The plastics sector, which has already been slated for considerable investment in coming years, holds vast opportunities for Western business. Current plastics consumption, just a fraction of Western levels, will rise rapidly as economic restructuring leads to greater use of plastics in applications such as packaging, construction materials, machinery and vehicle manufacture, and consumer goods. Even current plans for adding more than 1 million metric tons to plastics capacity in the former Soviet republics during the 1990s will be insufficient to keep up with soaring demand. Thus, attractive export opportunities can be expected for Western and some Eastern European producers in the short term. This is particularly true for more processed forms of plastics and for more sophisticated products like engineering plastics.

In the longer term, even greater opportunities exist for Western firms to assist in building new plastics capacity or to acquire existing plastics producers. There are a number of good potential takeover targets in plastics, especially since this was a priority sector for investment in recent years. Republics that show the most promise in this sphere are Russia, Ukraine, Kazakhstan, and Azerbaijan.

Chemical fibers are not a promising sector for Western investment. Demand for chemical fibers is expected to remain weak for much of the 1990s, as the textile sector is hit hard by economic restructuring. Domestic producers of chemical fibers are not very modern or sophisticated: The percentage of three relatively progressive fibers—polyester, acrylic, and polypropylene—in total chemical fibers output in 1990 was a very low 32%. Thus, there are relatively few attractive takeover targets or joint-venture partners. Notable exceptions include the new Blagoveshchensk complex in Russia, which will start up polyester fiber production in 1992. This plant is being built by a Japanese firm and will



use a Du Pont process. Other attractive projects are the large Mogilev polyester fiber complex in Belarus, which has been expanded in recent years, and the Novopolotsk complex in Belarus, where new acrylic fiber capacity was added in the late 1970s by Western firms. The most attractive republic for chemical fibers is Belarus, which produces an impressive amount of synthetic fibers, especially polyester and acrylics.

The paint and dye sector is also a good one to stay away from, thanks to the extremely old age and backward state of existing facilities throughout the former U.S.S.R. Almost no new paint or dye capacity was built during the 1980s, and a disturbingly large part of existing capacity dates from before the 1960s. Beginning in the mid-1990s, however, good sales opportunities likely will develop for Western suppliers of these products. This is particularly true for paints, since by that time a more competitive environment will necessitate better quality paint for use on manufactured goods. Domestic paint output will hardly be able to meet this new demand since much existing capacity will likely be shut down.

Beginning in the late 1990s, Western firms may find it attractive to build new paint and dye plants in the republics to feed the growing demand for high-quality output. But the high degree of sophistication of paint manufacture in the West and the transportability of these small-batch products may lead Western paint and dye makers to continue exporting output produced in the West.

Pharmaceuticals will be revolutionalized in the former Soviet Union in coming years by rapid expansion in Western investment, particularly in over-the-counter products. The shortage of medicines is so acute that even precious hard currency and oil have been used in recent years to import pharmaceuticals. Thus, Western drug manufacturers likely will find excellent sales opportunities for products ranging from simple over-the-counter drugs to more sophisticated medications for cancer and heart and other chronic diseases. Western firms also have the opportunity to replace East European suppliers of pharmaceuticals to the republics, since the East Europeans' previous advantage of selling their medicines for rubles rather than dollars on the domestic Soviet market was eliminated in early 1991.

Western firms are also likely to set up production facilities in some republics in coming years as demand increases. Some acquisition of existing producers might take place, but most Western firms will prefer to set up their own pharmaceutical production and distribution centers. Perhaps no other sector of chemicals will offer such vast opportunities to Western investors as pharmaceuticals in the coming years. Republics that offer the best opportunities in pharmaceuticals include Russia and Ukraine (because of their huge market size) and the Baltics and Belarus (because of their relatively high living standards).

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as much promise as pharmaceuticals. Here, too, there is a lot of unsatisfied demand for these consumer-oriented chemicals. These chemicals are still something of a luxury throughout the republics, however, and will remain so until the buying power of the average person rises to a decent level, something that will take well into the 1990s.

Thus, sales by Western producers will remain rather modest over the next few years and will be directed at the emerging upper class under the new market system. As in the case of pharmaceuticals, Russia, Ukraine, the Baltics, and Belarus will initially provide the best market for Western soaps, detergents, perfumes, and cosmetics. By the late 1990s, the economies of these and other republics probably will recover sufficiently to allow for much improved sales by Western producers, as well as some production of higher quality products within these republics.

Organic chemicals, which include a large number of bulk petrochemicals used to manufacture finished products, also offer a wide array of opportunities for Western companies. Russia and Kazakhstan, with their abundant oil and gas reserves, make natural candidates for large-scale petrochemical complexes. Western firms are expected to establish a number of joint ventures or wholly owned subsidiaries in these republics to produce various organic chemicals either for processing domestically or export. Because Eastern Europe is expected to de-emphasize its bulk organic chemical synthesis operations during the 1990s—now that it no longer receives Russian and Kazakh oil at below-market prices—Western firms may find these countries, as well as others further West, a potential market for bulk petrochemicals produced in Russia.

Demand for certain organic chemicals will be strong within Russia. Ethylene and propylene will be in demand to produce plastics, chemical fibers, and other products; and methanol may be in demand to help make methyl *tert*-butyl ether, used in the manufacture of unleaded gasoline. The market to other former Soviet republics during the 1990s will be much more limited because of their very large domestic production, but some spot sales may be possible.

Synthetic rubber demand will drop in coming years because of lower military expenditures. However, opportunities still exist in this sector. Demand for special-purpose rubbers will actually rise, since this type of synthetic rubber was underproduced in the former U.S.S.R., accounting for less than 20% of total rubber output. Demand for certain rubber products will increase as well. For example, more demand for cars and greater use of trucks to haul freight will increase demand for tires. Thus, Western tire firms, in particular, could find very lucrative opportunities for supplying the huge Russian, Ukrainian, and other markets.

Overall, the chemical industry of the former Soviet Union faces immense challenges during the 1990s as the economies of individual republics move to a market system. The magnitude and difficulty of these challenges are increased by the very poor state of this chemical industry at present. After more than 70 years of mismanagement under a faulty economic mechanism, one cannot help but wonder where the chemical industries of Russia, Ukraine, and other republics would be today had they been developing under a more rational economic system.

But present hard realities open up vast business opportunities for Western chemical firms. Western capital will be needed to rebuild and restructure the chemical industry of all the republics. Western suppliers of chemical products should see continued and expanding sales opportunities in the 1990s, especially for small-batch and specialty chemicals.

Although the Russians, Ukrainians, Kazakhs, and others lack hard currency to pay for new plants and chemical imports, innovative solutions exist. For instance, goods can be bartered, as Occidental Petroleum has done, exchanging its superphosphoric acid for Russian and Ukranian ammonia, urea, and potash. This particular agreement, signed in 1973 and intended to continue through 1997, foundered on the political and economic chaos of the region during the past year. However, it illustrates the potential value of barter arrangements in chemicals to both Western partners and former Soviet republics. A recent agreement to barter hundreds of millions of dollars worth of Polish pharmaceuticals and other consumer goods for Russian oil and natural gas offers another example of the possible future importance of barter to Russian chemical trade.

Another option for Western firms seeking to do business in the former Soviet republics is to accept a stake in the business by forming joint ventures. Though business conditions are extremely risky at present, this risk can be reduced by a series of measures, including minimal up-front investment and careful choice of location and sphere of activity. Moreover, the long-term growth potential for this huge market of nearly 300 million consumers is simply too great for many Western chemical makers to ignore. ☐

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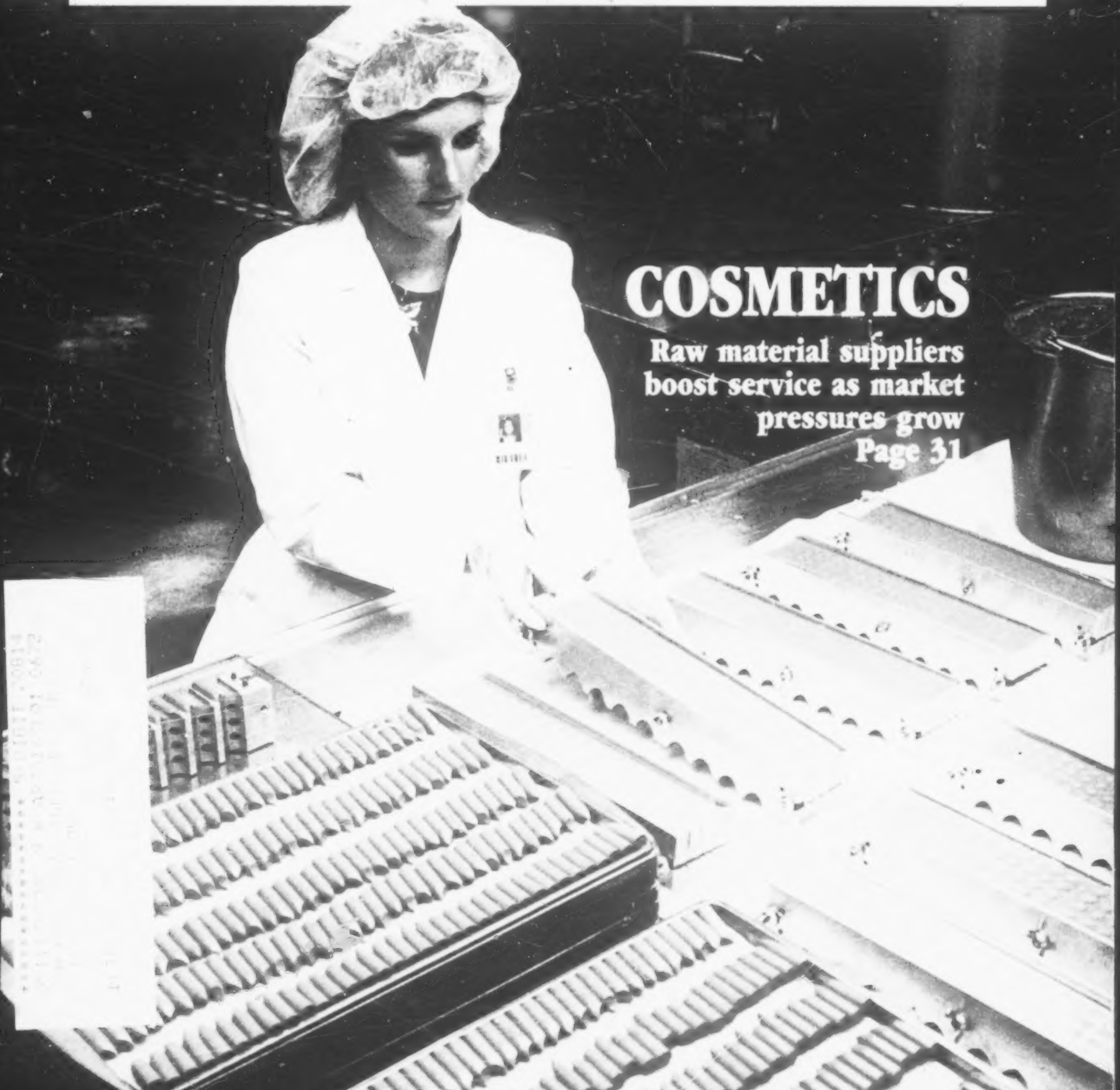

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Raw material suppliers boost service as market pressures grow
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CHEMICAL & ENGINEERING NEWS

C&EN

APRIL 20, 1992

NEWS OF THE WEEK

- DNA fingerprinting is a valuable tool for solving criminal cases, says National Research Council panel, but strict technical standards for tests must be devised. Page 4
- Union Carbide plans to sell its remaining interest in Union Carbide India Ltd., including its battery business and the plant at Bhopal, site of the 1984 methyl isocyanate disaster. Page 4
- Englehard develops family of refinery cracking catalysts that dramatically increase yields of isobutylene—a precursor to oxygenates for use in gasoline reformulation. Page 5
- Exhibit, symposium at Beckman Center for the History of Chemistry in Philadelphia honor noted organic chemist, the late Robert Woodward. Page 5
- New York, eight other states, and two environmental groups sue EPA for not issuing final permit rules as mandated by the Clean Air Act. Page 6
- Gradual phaseout of persistent toxic compounds used in or produced by industrial processes urged by U.S.-Canadian commission. Page 6

COVER: Worker at Maybelline's North Little Rock, Ark., plant removes lipstick from molds. Photo by Mark Morgan Photography

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Sweden's Nobel Industries is scrambling to get back on track following financial problems and bank takeover. ■ U.K. capital spending is forecast to be down again this year. Page 9

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NSF study predicting shortfall of scientists wasn't accurate, but was used to justify increased funding requests, speakers at House hearing charge. ■ Chemical industry worries U.S. policies will affect its trade advantage. ■ Destruction of Iraqi chemical weapons is expected to begin this summer. Page 14

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A protein that binds specifically to cisplatin-DNA adducts has been found. ■ Durable, low-power electrochromic system will have applications in electrocatalysis and automotive design. ■ Scrap tires or heavy residual oil can be used with coal to produce liquid synthetic crude oil. ■ As use of alternative fuels begins to be phased in, producers and consumers will feel effects in their wallets. ■ Studies of fullerenes show they can have different shapes and can be made from ordinary types of coal. ■ Crystal structure of enterobactin bound to vanadium(IV) has been elucidated. ■ New method for coal liquefaction is being readied for commercialization. ■ Organized assemblies of molecules—molecular systems—can be designed to deliver drugs or destroy chemical warfare agents. ■ A metallated polymer may serve as a molecular wire. Page 19

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600, TDD (202) 872-4432
John Kistler Crum, Executive Director
Robert H. Marks, Director, Publications Division

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Joseph A. Dixon; *President:* Ernest L. Eliel; Richard L. Deming, Judith C. Giordan, William P. Jencks, and Gary J. Long

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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189, outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
(For list of offices see page 79)

Office of Ombudsman: (800) ACS-5558, No. 8-5

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LETTERS

Cold fusion

In Wesley Murbach's letter to the editor (C&EN, March 9, page 3) he questioned the feasibility of cold fusion because, seemingly, the process appears to be much too simple. I am not a staunch believer that cold fusion can be achieved, but Murbach's comments encompass a larger issue. This is the criticism, and sometimes ridicule, that is often directed toward new ideas when the ideas don't conform to existing theories. I emphasize theory strongly because so much of chemistry and physics is based on theoretical concepts. Those who are quick to criticize new ideas may have forgotten that many existing scientific "facts" are in actuality educated guesses.

Brad Buecker
Springfield, Ill.

Oxygenated fuels

When the General Accounting Office (GAO) issued the report entitled "Oxygenated Fuels Help Reduce Carbon Monoxide," dated August 1991, they also invited readers to obtain more information from the appropriate authorities in the cities under study. I did that, and am left wondering about the wisdom of the project.

First, let us consider the good news. In all areas, there has been a steady reduction in CO levels over a period of years. In the case of Las Vegas, for example, a crude estimate of ambient CO for the worst days measured at one site and adjusted for a presumed increase in gasoline consumption dropped about 60% over a 15-year period. (On the other hand, two winters of oxygenated fuel use there perversely showed little change in CO and an increase in NO_x.) Albuquerque reports a 40% decline over six years in ambient CO in winter at the site with the highest level. During a decade of measurement at Arizona sites, the number of days in which the ozone level exceeded standard also diminished, even though peak readings did not. And then, there was roughly a 15- to 20-fold reduction in atmospheric lead at sites in Colorado and Arizona that would result from the phaseout of cars without catalytic converters using leaded gas. These are all to the good, but they are not the result of using oxygenated fuels.

What I am concerned about is this: The GAO report claims the use of oxygenated fuels alone will "not ensure compliance with national CO standards." Yet we are forcing expenditure of billions of dollars for the construction of refinery units mainly to manufacture methyl *tert*-butyl ether, the oxygenate of choice. As for ethanol, other sources claim the fermentation process is not economical without a subsidy, and for the required production would compete with food supplies. In any event, with ethanol, vaporization losses reportedly exceed contemplated standards.

I would think that incentives and penalties to reduce the consumption of gasoline would be far less costly and more effective than what we have embarked upon. But I guess that as long as the Saudis keep supplying us with cheap crude, there is no hope of having a conservationist policy prevail. Is this another example of "you can't get there from here"?

Charles V. Berger
Western Springs, Ill.

NIH's strategic plan

I wish to respond to the story on the National Institutes of Health's strategic planning process (C&EN, March 9, page 15).

Although the story was generally correct and accurate, I don't think the headline and blurb accurately reflect the strong endorsement of scientists and other participants to the NIH strategic planning process.

I attended two of the five regional meetings (Los Angeles and St. Louis). There was strong, even enthusiastic, support for a strategic planning process. In general there was strong commendation and appreciation expressed to Bernadine Healy and her staff for initiating the process.

The final strategic planning document will probably be much shorter, much more general, and more inclusive than the "framework for discussion" documents distributed in preparation for these meetings. The purpose of these meetings was to solicit suggestions, criticism, and input to the process. That is exactly what the biomedical research community did at these regional meetings.

Correction

- April 6, page 6: The third anniversary of the announcement of cold fusion was March 23, not March 27.

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ISP's in-house salon allows thorough testing of raw materials used in customers' new and existing products

Cosmetics Suppliers Rally To Meet Consumer Concerns

Susan J. Ainsworth, C&EN Houston

Judging from its several years of annual sales growth of roughly 3%, the nearly $17 billion U.S. consumer market for cosmetics and toiletries is a mature business. But it is far from being stagnant. As Janet Kosiek, a product manager in Lonza's performance chemicals group, Fair Lawn, N.J., puts it: "We are in an industry that's in a state of constant change."

Perhaps the biggest change in the industry has been its marked consolidation. Cosmetic and toiletry companies continue to merge as do the companies that supply their raw materials. In addition, government regulations are tightening their collective grip on producers of cosmetics and toiletries. "Regulatory changes have driven cosmetic product development for a long time. However, we're seeing an acceleration in this area based in large measure on volatile organic compound (VOC) reduction," says Ro Oteri, a marketing manager at International Specialty Products (ISP), Wayne, N.J.

At the same time, consumers are becoming more concerned about the mildness and environmental friendliness of personal care products. Some want hair and skin products that are less irritating to skin and eyes. Some want less packaging. Some demand that the products they buy not be tested on animals and that they contain natural ingredients. Many in the industry believe they are so busy reacting to regulations and customer expectations that there is less time available now for innovation and new product development.

Consumers also want more value for their dollar. This is the "biggest long-term trend in the personal care market. Consumers are looking for more performance from the products they use, without any substantial change in cost," says Frank J. Freiler, director of marketing for the Union Carbide subsidiary Amerchol, a specialty chemicals company specializing in the personal care and cosmetics industry. Consumers, he adds, increasingly are looking for single products that can do what two or three products used to do.

The bottom line is that marketers are being pressured to reformulate to meet these new demands. What's more, they are expected to do this with a leaner work force because their staffs have been combined and trimmed as a result of mergers.

Consequently, cosmetic and toiletry companies are calling on their raw material suppliers more than ever to help them meet these many challenges. In response, suppliers are fortifying their technical service programs. They have to be more knowledgeable than ever about their products and technology and must work closely with their customers to better anticipate and meet their needs.

Henkel photos

New formulations of personal care products help reduce skin, eye irritation

At the same time, raw material suppliers are suffering under their own consolidation pressures. "If you go back 10 to 15 years, the number of companies making surfactants and raw materials was much larger than it is today. Even though the number of 'available' companies has dropped, consolidation will continue," projects Larry Rosenberg, a consultant at Chem Systems, Tarrytown, N.Y. For example, companies will sell off divisions because they are underperforming or because they no longer fit their core objectives, he adds. As a result of this supplier-side reorientation, staffs at many raw material suppliers are mirroring those of their customers—leaner and more streamlined. The upshot: Suppliers need to meet more of their customers' needs and do it more efficiently than ever.

These pressures are having an impact on the direction of the cosmetics and toiletries business. "In the 1990s, we will most likely see continued consolidation and a focus on manufacturing efficiency and distribution rather than on the development of new products. We seem to be moving toward a commodity-type environment," notes John V. Venegoni, business manager for personal care products at Stepan, a specialty chemicals firm in Northfield, Ill.

Despite the many challenges this cosmetics and toiletries market poses, many companies still choose to compete in it. Currently in the U.S. more than 500 companies are peddling in excess of 20,000 brands. On the raw materials side, roughly 150 firms supply cosmetic and toiletry additives. One attractant may be the ample size of the industry. The value of industry cosmetic shipments was $16.8 billion in 1991, reflecting only 3% growth in constant dollars over 1990, according to the 1992 Industrial Outlook report on cleaning preparations and cosmetics issued early this year by the Department of Commerce. Net exports represented 6% of total shipments, the report adds.

The cosmetics and toiletries business encompasses many markets. The Commerce Department includes shaving preparations, fragrances, hair preparations, dentifrices, and cosmetics in its cosmetics classification. The companies producing products within these categories are engaged in manufacturing perfumes, cosmetics, bath salts, body powders, colognes, creams, lotions and oils, dentifrices, denture cleaners, deodorants, hair coloring preparations, tonics and scalp conditioners, home permanent kits, manicure preparations, mouthwashes, shampoos, soap-impregnated powders, suntan lotions and oil, talcum powders, toothpastes and powders, premoistened towelettes, and other toilet preparations.

Sales of perfumes are outpacing other segments, says a February 1991 report on cosmetic and toiletry additives done by the market research firm Freedonia Group, Cleveland. These data, like all growth rates in Freedonia's report (unless otherwise noted), include growth as a result of inflation. Perfumes are likely to expand 8.3% per year to $595 million in 1995. Perfumes generally have short product lives, which means that marketers are always developing products and introducing new ones. This factor and the trend toward perfumes targeted at specific demographic markets are expected to continue to fuel demand.

Sales of hair preparations are expected to increase 7.7% annually to $830 million in 1995, reports Freedonia. Growth in this market, dominated by surfactants and hair polymers, is being driven by such new products as gels, softer styling sprays, and spritzes. Trends include a move away from heavy conditioners and back to cream rinses, and the expansion of ethnic hair care product markets.

Shaving preparations are likely to expand more than 7% per year to $375 million in 1995. Trends in this market include a movement toward sensitive-skin formulations, skin conditioning products, and an expansion of products targeted at women. Meanwhile, cosmetic preparations markets will likely expand 6.8% per year to $275 million in 1995 based on strong demand for skin care products, many of them incorporating sunscreen additives. Dentifrice market growth is likely to occur because of increased consumer concerns about gingivitis and plaque, as well as new products directed at children.

Cosmetic and toiletry additives are a much smaller part of the $16 billion-plus cosmetics and toiletries finished goods market. Sales in the U.S. are forecast to grow 7.4% annually to $2.7 billion in 1995, with real growth (excluding inflation) reaching only 3.6% per year, according to the Freedonia study. Emollients and moisturizing agents make up the largest product segment in the market; they are expected to expand 7.2% annually to $880 million in 1995, Freedonia reports. "Growth will be based on demand for skin care compounds from a maturing population, increasing use of male-oriented products such as sensitive-skin shaving preparations, and healthy sales of sunscreen products." Opportunities will also arise for suppliers and marketers of vegetable and castor oils and other natural ingredients, says the report.

Freedonia expects fragrances demand to increase 8.8% per year to $865 million, "benefiting from the penetration of new target markets and ongoing product introductions." Although consumers currently favor natural essential oils, Freedonia anticipates makers of synthetic aroma chemicals will compete by introducing more accurate recreations of natural scents.

Hair polymer sales are expected to expand 7.2% per year to $85 million in 1995. Growth likely will come from strong demand for styling products such as mousses, the addition of conditioning agents in shampoos, and the introduction of hair waxes that impart shine and manageability to hair. Sales of waxes have already taken off in Europe, says the Freedonia study.

Freedonia forecasts that the use of surfactants in shampoos, cosmetics, and toiletry products (excluding soaps) alone will grow 3.6% annually to reach 582 million lb in 1995. Niche markets such as cosmetics for various ethnic groups and sun-care protection products will present opportunities for cosmetic companies marketing such end-use cosmetics and toiletries. Raw material suppliers who develop and market natural-based and milder formulations and surfactants with less residual odor will be able to achieve faster growth, the consulting firm predicts. Michael Gransky, a sales manager for Hüls America, agrees and adds that surfactants that contain no animal by-products and that are readily biodegradable have also gained prominence in the market within the past year.

Good opportunities are anticipated for amphoteric surfactants, because they are natural and extremely mild to the skin and mucous membranes, and have less residual odor—two characteristics in demand right now. Amphoterics, although they account for less than 1% of the total market and are among the most expensive surfactants, are important ingredients for many personal care products such as shampoos, and liquid and bar soaps, says another Freedonia report on surfactants completed in July 1991. With a very small sales base, and many newly developing applications, amphoterics are growing faster than the other three surfactant groups—anionics, nonionics, and cationics. Driven by the personal care market and increasing industrial specialty applications, amphoteric surfactants demand in all end uses is expected to expand 5% annually to 55 million lb in 1995.

Sales for another group of additives, those for sunscreens, are expected to increase 8.4% per year (including inflation) to $45 million in 1995, an increase that is benefiting from growing concern about the harmful effects the Sun can have on skin, coupled with the increasing inclusion of ultraviolet absorbers in items such as skin creams, shampoos, and lip balms, notes the Freedonia study. The silica division of Degussa, in Dublin, Ohio, has been riding this wave with an ultrafine-particle-size titanium dioxide product that blocks UV radiation without the white pigment usually associated with the compound. The absence of the white pigment makes the product suitable for use in a variety of cosmetic products, including mascaras, makeups, and lipsticks. Formulating products other than traditional tanning products is "a rapidly growing market," says Richard Cavagnaro, product manager of the division.

Demand for thickening agents, used in

Sales of cosmetic, toiletry additives will grow roughly 4% annually through 1995

$ Millions	1990	1995	2000	% annual change (1990–95)
Emollients & moisturizing agents	$ 621	$ 880	$1208	7.2%
Fragrances	567	865	1300	8.8
Surfactants	251	345	470	6.6
Propellants	138	180	220	5.5
Hair polymers	60	85	120	7.2
Biocides	55	75	100	6.4
Thickening agents	46	65	90	7.2
Nacreous pigments	35	45	57	5.2
Sunscreen additives	30	45	65	8.4
Other cosmetic additives	111	155	200	6.9
TOTAL	$1914	$2740	$3830	7.4%
ADJUSTED TOTAL ($ millions, 1990 = 100)	$1914	$2280	$2710	3.6%

Source: Freedonia Group

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nearly all cosmetics and toiletries, likely will grow 7.2% per year. Meanwhile, biocide sales can look for increases of 6.4% per year, totaling $75 million in 1995, says Freedonia. Nacreous pigment sales are expected to experience growth of only 5.2% per year because of the trend toward makeup that imparts a matte finish rather than the pearly luster provided by nacreous pigments. "Other cosmetic additives, consisting of such widely used products as dyes and pigments, will mirror gains in aggregate cosmetic and toiletry product shipments," says the Freedonia study.

Anionics most widely used in cosmetics, toiletries

Millions of lb	Consumption 1980	1985	1990	1995	2000
Anionics	155	233	345	415	485
Nonionics	37	49	55	62	70
Cationics	25	41	62	75	88
Amphoterics	13	16	25	30	38
TOTAL	230	339	487	582	681

Source: Freedonia Group

Soaps manufacture uses most personal care surfactants

Millions of lb	Consumption 1980	1985	1990	1995	2000
Soaps	512	610	750	795	840
Shampoos	170	266	405	485	567
Other cosmetics & toiletries	60	73	82	97	114
TOTAL	742	949	1237	1377	1521

Source: Freedonia Group

Technical service must be strong

Even while some segments of the additives market are ripe for growth, suppliers are having to work harder than ever to tap into them. Their customers, the cosmetic marketers, want suppliers to do more of the leg work and screening for them to streamline the cosmetics formulation work, says Hüls America's Gransky. To keep their customers happy, suppliers need to make the technical service component of their businesses stronger than ever, he adds.

For one, "cosmetics are much more elegant and sophisticated than they used to be. The simple cosmetics of 30 years ago have been replaced with technically more advanced products. That's why [cosmetic marketers] appreciate more customer service," says William E. Rosen, president of ISP subsidiary Sutton Laboratories in Chatham, N.J., a leader in the preservatives market.

But more significantly, this trend toward stronger technical service "goes hand-in-hand with the consolidation trend," says Lonza's Kosiek. Marketing companies that have merged with other companies have fewer people doing the same jobs so "they have higher work loads and they need help." ISP's Oteri adds, "Consolidation among the supplier's customer base and also paring down of our customer's R&D staffs," means the customer is placing "a greater requirement on suppliers to deliver much more applications data in support of their products, especially new ones."

Kosiek notes, "These days doing technical service is more than putting formulas together. Marketers want support on how our raw materials work and why they work. Customers want to know what variations in a formula will do and want a good general understanding of the chemistry." For example, "We know betaine [a carboxylate surfactant] combined with an anionic surfactant makes a good shampoo, but we also have to know why a certain ratio works best and what happens if we change the ratio or the pH, etcetera. A company that can explain why its product works or does not work has credibility, and credibility is important in this business."

There is also, Oteri says, "a developing trend among suppliers to work closely with customers at earlier stages of product development. This benefits both parties—the customer gets new technologies to the market faster while the supplier's product development process becomes more efficient."

Hüls' Gransky observes: "Companies are running leaner and they don't have the qualified personnel and money to screen 20 to 30 products to find the most suitable one. They are more sensitive than ever about the time outlay. Our people must be sharp and give them the most appropriate offering the first time around. When we do that, we shorten the customer's time to market."

One way suppliers and cosmetic companies can work together more closely is by forming partnership-type alliances, says Matthew F. Jurczyk, product manager for personal care chemicals at Akzo Chemicals, Chicago. With quality processes being adopted by many companies, these types of arrangements are becoming more common, he adds. "As the industry becomes more complex and segmented, our clients have unique needs and tight specifications on existing products. We try to accommodate them by customizing our products to meet those needs."

To respond to today's market environment, Oteri says raw material suppliers are also teaming up. "In order to meet developing environmental and performance needs," he says, "suppliers can't develop products in isolation. For example, research for tomorrow's new hairspray resins is stimulating ISP's scientists to become intimately aware of developing advances in packaging technology as well as progress of other chemical suppliers in the propellants and solvents areas."

Another trend that is emerging as competition grows more keen is that some companies are working harder to bring new innovations to the cosmetic companies more often rather than serve a reactionary role. Ninety percent of the time, marketers drive the trends and raw material suppliers scramble to meet their needs. That's because the cosmetic companies have direct customer contact and generally pick up on the trends first.

One company, which does not want to be identified to avoid alerting its competition, has adopted a market research program that will allow it to get closer to the market and better tuned into consumer demands. "This will allow us to be a more efficient supplier of technology and innovation to our customers," a marketing manager at the company adds. "As a supplier we can bring the most value to our customers if we can help them kick off a trend."

Indeed, cosmetic raw material suppliers have had to refocus and accelerate their technical service support operations to retain and please valued customers. Making this even tougher is that suppliers' businesses are also merging, closing as a result of unbearable regulatory pressure, or becoming leaner.

The anionic surfactant business, for example, is down to only a handful of suppliers, says Stepan's Venegoni. "Regulatory pressures have forced several companies in this business to close their doors. The companies that are left have been focusing on increasing capacity to meet the increased demand for their products."

Focus on logisitics rather than innovation

With the pressure to pick up this kind of slack in the market, "it appears that both suppliers and their customers have less time and fewer resources available for new product introductions," says Venegoni. For example, "in the shampoos business, there seem to be fewer brands on the shelves than there were just five years ago and a handful of companies make most of them," he notes.

That kind of culling is true not only for the shampoo market. Almost 60% of cosmetic and toiletry sales are controlled by 10 companies, notes the Department of Commerce report. Says Venegoni: "Companies are taking advantage of their economies of scale. It appears that this business, particularly in the shampoo area, is becoming commodity-driven."

Contributing to this shift in emphasis from innovation to logistics is the stifling effect that the consolidation of the industry has had on efforts of many entrepreneurial-type companies, says Venegoni. Many of these companies have been acquired or merged with larger organizations or exited the market as a result of the escalating costs of doing business.

Another obstacle to new product innovation is that "the cost of introducing a new product has become exorbitant," says Venegoni. "Developmental and marketing costs are reaching the point where many companies can no longer afford to develop and launch a new product unless it can offer unique benefits to the consumer."

Regulations stifling product development

Complying with regulations also is adding significantly to the cost of introducing a new product. "In general, a great deal of our customers' R&D time is being spent reformulating existing products to meet regulatory requirements," says Venegoni. "That means there are fewer resources available for exploring new products."

Indeed, the biggest change in the cosmetics and toiletries business during the past few years has been the increasing pressure of regulatory issues, led by the actions of the California Air Resources Board (CARB), says Lonza's Kosiek. At its annual meeting last month, the Cosmetic, Toiletry & Fragrance Association (CTFA) identified air quality legislation as its number one concern currently.

There has been some good news for the industry, though. In January CTFA was successful in persuading CARB to modify its proposed regulation governing the VOC content of personal fragrance products. The new proposal, which was adopted by the board at a Jan. 9 hearing, was modified to take into account the technical impossibility of reformulating existing fragrances to reduce the alcohol content and to allow more time to phase in more realistic VOC limits for future products, says CTFA.

The regulation adopted by CARB exempts existing personal fragrance products from the VOC limits and provides that all "products in development" by April 1, 1992, will be exempted, provided those products are registered with CARB by July 1, 1993, and sold in California prior to Jan. 1, 1994. Future personal fragrance products will be subject to VOC limits in two stages taking effect on Jan. 1, 1995, and Jan. 1, 1999.

Still, dealing with CARB's regulations for personal fragrances is just one third of the battle. The first wave of activity occurred back in 1988 when California amended its Clean Air Act and then set an informal goal to reduce VOC emissions from consumer products 50% by the year 2000. The antiperspirants and deodorants category was the first one targeted; in November 1989, the board adopted regulations that would dramatically reduce VOCs in these products by 1995. The regulation poses the biggest threat to aerosol producers, who will find it difficult to reformulate to meet such a deadline, says Thomas J. Donegan Jr., CTFA general counsel. With that in mind, CTFA is now pursuing several initiatives to obtain more time and more reasonable VOC limits for this category.

The second wave of CARB activity took place in 1990, Donegan says, when the board proposed the "first really broad consumer products regulation covering, among other things, five different personal care product categories—hairsprays, hair styling gels, hair mousse, nail polish remover, and shaving cream." The most worrisome to the industry is probably the hairspray portion of the regulation, which now calls for an 80% VOC limit by January 1993. And he adds, "CARB wants to change that limit to 55% by 1998 and that's a problem. This is what CARB calls a technology-forcing regulation. CARB figures if it holds our feet to the fire long enough, someone will figure out a way to reformulate to meet their limits."

Although most of the air quality activity is now centered in California, other states are following close behind. For example, late last month New York State's environmental board approved a proposal that will set VOC limits similar to those of California for antiperspirants, deodorants, and hairsprays, says

Workers in Maybelline's plant in North Little Rock, Ark., assemble eye shadow makeup kits

Donegan. Lonza's Kosiek adds, "People are afraid there will be 50 different regulations they have to comply with, but that's very unlikely because states tend to model their laws after one another." Still, Donegan says, regulations from state to state can differ just enough—for example in their enforcement dates—to make life difficult for producers.

"These regulations and issues will impact everything in personal care" and will dictate everything from what products are developed to what drives technology in the future, Kosiek adds.

Reformulations of existing products designed to get around these regulatory hurdles are already becoming evident in the marketplace. For example, last year the European Designer Fragrance Division of Cosmair introduced Anais Anais' Voile de Parfum, a fragrance product made using alcohol-free technology. The company claims its product, which replaces a fragrance's alcohol content with moisturizers, has proven so effective and has been so well received by consumers that Cosmair has decided to launch other such products. Last month it brought to market its Paloma Picasso Satin de Parfum, another moisturizing perfume mist without alcohol. Still, Cosmair has not been successful in exactly re-creating the original alcohol-based scents. The company claims the new product form "has all the elegance of the Paloma Picasso's original perfume, but that the absence of the alcohol removes the headiness or topnotes."

Indeed, reformulation to comply with regulations has its challenges. Says ISP's Oteri: "The promulgation of 80% VOC hairspray products regulation in California and other states did not leave industry very much time to respond through innovation." Today's hairspray resins were designed for anhydrous systems. Cosmetic industry groups have estimated it could take as many as seven years to develop new resins from scratch, he adds. ISP responded to the rapidly changing market requirements by making incremental changes to their popular Gantrez brand ES hairspray resins. "The new products—Gantrez brand V resins—mitigate the deleterious effects of water in 80% VOC hairspray formulations. Marketers can now comply with the regulations without compromising hair holding, drying time, or tactile performance properties," adds Oteri.

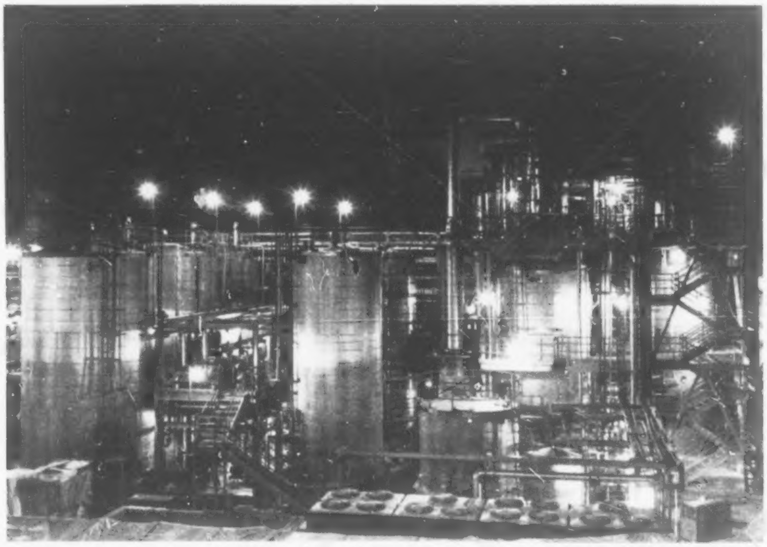
Similarly, within the past two years Akzo Chemicals has introduced a new product into the hair care market to help its customers address changing regulations. The trademarked product, Arquad HTL8, a branched quaternary salt, is offered in a high active liquid version using water as a solvent. This helps meet the need to develop formulations without using alcohol-based products, says Akzo's Jurczyk. Cosmetic companies are increasingly concerned about the odor, safety, and handling issues associated with alcohol, he adds. "Arquad HTL8 offers the kind of intense conditioning normally associated with dialkyl quaternaries typically available in paste or solid form. Formulators would rather handle liquids, which can be easily pumped. Solids must be melted—creating another processing step."

Raw material suppliers are also experiencing the effects of another piece of legislation originating in California—Proposition 65. This law, adopted as a voter initiative in 1986, requires the state to identify substances known to be carcinogens or reproductive toxicants. Now, the state has identified over 400 such chemicals. The manufacturer of any consumer product containing such a chemical, even as a contaminant, is required to warn of exposure to such chemicals unless they can demonstrate there is no significant risk from that exposure. Significant penalties can be imposed for failure to warn. Although food, drugs, and cosmetics and medical devices in compliance with other federal and state safety requirements are exempted from some cancer-warning requirements of Proposition 65, that exemption has been challenged in court in California. These products remain subject to warning requirements for reproductive toxicants, says CTFA.

Because of continuing concerns about application of these warning requirements, cosmetic and toiletry companies are taking a careful look at their formulas, and are looking to their suppliers to tell them with great certainty and accuracy what is in the raw materials they are buying. Raw material component disclosure "is not a clear-cut, black and white issue," says Jurczyk. Very few companies sell chemically pure materials; most ingredients are actually complex mixtures and may contain numerous by-products, he explains.

The suppliers that will survive the regulatory environment created by rules such as Proposition 65 "will be those that can provide the greatest toxicology and regulatory support for their products," says Jurczyk. As a result, "more companies need fully staffed regulatory and toxicology departments to address these types of issues and provide sophisticated responses to customer inquiries. Even in the last two years, I have seen the number of these types of customer requests jump dramatically."

Likewise, Barbara Pagliocca, marketing manager for chemical specialties at



Henkel's alkyl polyglycoside surfactants plant in Cincinnati

Hüls America, observes: "Our customers are much more interested in getting toxicological information up-front as well as dermal testing and safety data. They now have to be much more precise about what is in their products." As a result of these concerns, companies are cutting down on the number of new raw materials they sell unless those materials serve a new function or provide a dramatic cost savings, says Pagliocca.

Dugussa's Sipernat precipitated silicas serve as thickening, adsorption agents in cosmetics

Alternatives to animal testing sought

The sticky issue of animal testing is another factor that is driving companies to reformulate existing products and ingredients rather than develop new ones. For several years some cosmetic companies have stepped up efforts to promote the fact that their products are not tested on animals, in response to consumer concerns. For instance, the Body Shop, a fast-growing cosmetic company that prides itself on social activism, says it "insists that the manufacturers and suppliers of our ingredients provide regular written confirmation that they have not carried out any animal testing—nor has any testing taken place on their behalf—on those materials within the previous five years."

Indeed, marketers have been ahead of raw material suppliers in making these claims, possibly because it has been more crucial to their businesses and possibly because making such claims has been easier for them. "Even if a cosmetic company says a final formula is not tested on animals, there's a chance that somewhere down the line its ingredients were animal tested by one of their suppliers or someone else in the industry," says one source.

But raw material suppliers are experiencing more of the heat of the debate on animal testing and they are moving toward the possible solution of using alternative tests—a still uncertain path that many cosmetic and personal care companies have already taken. For example, this past January the American subsidiary of Rhône-Poulenc signed a scientific collaboration agreement with InVitro International, a company that produces proprietary alternative tests that don't use animals. The tests can be used to evaluate the potential irritation to humans posed by a wide variety of chemicals and compounds found in cosmetics, household goods, and industrial products.

Rhône-Poulenc's surfactants and specialties division, Cranbury, N.J., is now using InVitro International's Eytex and Skintex methods to measure the irritancy and toxicity of its current products and in the joint development of low-irritation surfactant protocols. The Eytex and Skintex assays are based on highly ordered macromolecular models and have been used by major companies worldwide, says InVitro. These assays have consistently demonstrated the ability to accurately predict ocular and dermal irritancy, with an error rate of 7 to 10%, according to InVitro. "The Draize tests, which use live rabbits, have an error rate as high as 40% and are considered too costly and time consuming to use for optimizing product formulations," adds InVitro. Says James Manier, business director for personal care at Rhône-Poulenc's surfactants and specialties division: "The adoption of InVitro's advanced in-vitro methods will help us develop advanced surfactants and formulas that are nonirritating and will extend our leadership position in mildness."

Still, doing any testing other than tests in animals can be risky for raw material suppliers. The Food & Drug Administration recognizes no other safety tests as acceptable. Thus, raw material suppliers that opt not to test on animals risk facing liability issues later on, notes Lonza's Kosiek. "It gets into a real gray area."

The bottom line is that raw material suppliers still have to do what ultimately pleases their customers. "We are following the animal testing area very closely and are looking at alternatives. But we take our cues, not from the general public, but from our customers. We will do any testing that our customers feel is important and necessary," says one source.

If nothing else, the animal testing issue has made companies think harder about when testing on animals is really necessary—for both humanitarian and economic reasons. "There was a time when animal testing was done to more of an extreme, but for the last few years the efforts have been scaled back as much as possible by the industry," says Kosiek.

These days, Hüls' Gransky says, companies will animal-test only if they absolutely need to validate other test modes. Many companies are doing away with in-house animal testing. The expense and hassle of animal testing has forced many companies "to stay with their existing menu of raw materials" and launch a new product only if it will yield immediate benefits for the company, Gransky adds.

Consumers demanding mild formulations

Although regulations and animal testing issues are making it increasingly expensive and difficult for the industry to develop and launch new products, companies still have to stay innovative in order to meet consumer demands for new formulations.

Not surprisingly, consumers are thinking more than ever about product safety and are demanding milder hair and skin products. The controversy stirred up by various regulations and

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animal rights activists may be part of what's behind this trend. Another force driving the materials changes toward mildness may be the aging population, which is growing in size and thus becoming a major market, notes Kosiek. Older skin needs products that are less harsh and that have fewer degreasing additives. Some ingredients strip hair and skin of moisture much more than others, she notes.

Seeing this trend, Lonza and companies like it have focused some of their research efforts on "how to expand their product lines to make products that are more efficacious and safe," says Kosiek.

Amerchol's Freiler says during the past two years the firm has been working to expand its product line of natural glucose-based raw materials to add other functional properties to these materials. "One example is Glucquat R 125, a cationic material that adds substantivity to the known humectancy and mildness properties of our methylglucose-based materials."

Other companies are adding milder surfactants to their product portfolios and expanding capacity for them. For example, Rhône-Poulenc's surfactants and specialties division says it will soon announce a $5 million expansion of its Geropon sodium cocoyl isethionate (SCI) plant at Winder, Ga. This mild surfactant is used in bar soaps such as Lever 2000, which has gained great acceptance despite its recent introduction into a market dominated by mature brands. SCI also is used in liquid soaps, facial cleansers, and bath products. "We are looking at all of our primary surfactants to see how we can make them more natural, milder, environmentally safe and avoid testing them on animals. Everybody is looking at these factors; they are what is driving any new product development," says Rhône-Poulenc's Manier.

Henkel recently started up a 25,000-metric-ton-per-year alkyl polyglycoside surfactant plant at its Cincinnati, Ohio, production facility. The unit is part of an investment of more than $120 million that also includes a 40,000-metric-ton-per-year fatty alcohol plant, scheduled to begin operating in the third quarter of this year.

According to Anthony DeRose, vice president of Henkel's Cospha Division in Ambler, Pa., Henkel's new surfactants, tradenamed Plantaren, have very good foaming properties in the presence of sebum and are extraordinarily mild to skin and eyes as well as being biodegradable. Henkel's alkyl polyglycoside surfactants are being used in a variety of personal care applications including shampoos, hair conditioners, facial cleansers, and bath products. DeRose points out that its mild line of alkyl polyglycoside surfactants is made from renewable raw materials—glucose derived from corn and fatty alcohols from coconut and palm kernel oils.

Henkel is likely getting a lot of marketing mileage [illegible] of its products being natural based. That's because many consumers equate natural with mildness and safety. The trend toward "natural ingredients and natural-based products" has accelerated over the past few years. Fast-growing companies like the Body Shop have based much of their success on their marketing of so-called natural products, such as a foot scrub containing Greek volcanic pumice stone or a moisturizer based on mango butter and sweet almond oil. Avon has touted its new Anew Perfecting Complex for Face as based on glycolic acid, which is an alpha hydroxy acid derived from sugar cane. "Studies over the past 20 years clearly demonstrate that alpha hydroxy acids can improve the overall quality of the skin—minimizing the appearance of fine, dry lines and wrinkles," says Alex Znaiden, director of R&D at Avon Skin Care Laboratories, New York, N.Y.

Many raw material suppliers believe "the natural issue is more consumer perception than anything," says Kosiek. Thus producers of synthetic raw materials have an uphill battle convincing today's consumers that their products can be just as mild as natural-based ones.

Says John M. McChesney, manager of marketing communications for Ethyl's chemicals group in Baton Rouge, La., "Mildness and reduced toxicity are not necessarily tied to botanical-based materials. Many cosmetic chemists understand this and select raw materials with the desired performance characteristics." For example, the company's Ethylflo polydecenes "provide the performance and safety properties desired by the chemist and the consumer." These fully hydrogenated decene oligomers are base fluids with low toxicity

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Contrary to consumer perception, raw material suppliers are quick to point out that natural is not always better. For example, poison ivy is a natural product that is not good for skin contact, says Kosiek. Many synthetic products are purer, safer, and milder than naturally produced materials.

"There's a lot of inconsistency in nature. Nature does not grow itself according to specification," Huls America's Pagliocca points out. "The less controlled a production process is, the more you might expect to have problems," she adds. For example, cocoa butter substitutes have a narrow melting temperature range so it is easier to use them in a production batch than natural cocoa butter, which has a wider and less predictable range.

In general, the new breed of natural products are also harder to preserve, notes Rosen of Sutton Laboratories. "It can be done well, it's just more challenging." Certain ingredients such as some proteins and emulsifiers tend to inactivate the preservatives, he explains. "And if a preservative does not do its job, you know it. Its role is not a vague conceptual one such as is the case with emollients or humectants."

Natural ingredients are also much more limited in scope and functionality than synthetics. The challenge to formulators is to use more environmentally friendly ingredients but not to lose any of the performance of existing products. "It's easy to make a good performing product or an environmentally friendly product. It is hard to do both in one product," says ISP's Oteri. Consumers, he points out, no matter how much they want to support the environment, won't buy a more environmentally friendly product if it does not perform as they expect it should.

Producers of synthetic ingredients point out that natural-based raw materials are not always more environmentally friendly, either. For example, palm oil and coconut trees have to be treated with fertilizers and pesticides. "Then the oils must be treated chemically to get the surfactants," says Eric Spore, a product specialist in the olefins and derivatives division of Chevron Chemical, Houston, which makes additives for sunscreens and intermediates for a variety of personal care and cosmetic

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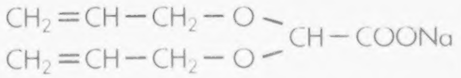

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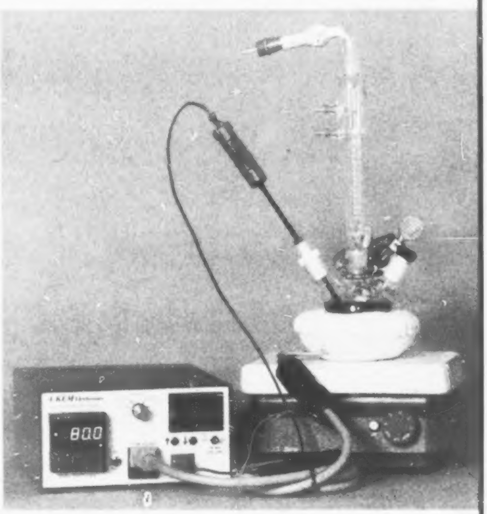

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products. "On a life-cycle basis, synthetics are safer, purer, and kinder to the environment," he adds.

Quest for value creates challenges

Another consumer trend that is driving new product development is the quest for value. The 1990s are marking a change in consumer psychology, CTFA president Edward Kavanaugh, said at the association's annual meeting. "There's a new focus on value, and value is now fashionable."

It is not surprising, then, that one of the biggest changes in the cosmetics and toileiries market recently has been the "explosive growth of two-in-one products," says Akzo's Jurczyk. Ever since Procter & Gamble introduced its Pert Plus product, which is a shampoo and conditioner in one, marketers have been trying to follow suit. Now, seven or eight producers have two-in-one shampoos. They realize that selling consumers on multifunctionality is easier than selling on the benefits of a "green" product, for example, because the consumer can more easily perceive a difference, explains Lonza's Kosiek. "That's why multifunctional products are the hottest thing in the cosmetics and toiletries business right now," she says.

The consumer gets the performance properties from a shampoo that usually required the use of an after-shampoo rinse or conditioner, says Amerchol's Freiler. As a result, "the consumer saves time, effort, and probably a little money," he adds. In skin care, the use of sunscreens in daily moisturizers and the addition of conditioning properties to cleansers are other emerging examples of this multifunctionality trend.

Many raw material suppliers are marketing their products with the same benefits in mind. For example, Akzo's Arquad HTL8 provides conditioning properties while acting as an emulsion stabilizer, says Jurczyk. Rhône-Poulenc's surfactants and specialties unit continues to develop its Jaguar guar-based polymers for two-in-one hair care products. The technology was developed to get around silicone technology, which is what Procter & Gamble uses in its Pert Plus, for which the company has patent protection. Stepan, however, has found a way to use silicone technology for multifunctional shampoos that is not included in Procter & Gamble's patent. Stepan's TAB-2 product allows formulators to suspend silicone, which provides conditioning properties, into a shampoo. The product has been on the market for about a year.

Indeed, raw material suppliers are having to jump through more hoops to thrive in their businesses. The increasing demands of consumers and various regulatory agencies are making life more difficult for cosmetics and toiletries producers and their suppliers are scrambling to help them meet these challenges. The cosmetics and toiletries business "used to be a black magic industry, but now that's changed," says Kosiek. "Raw materials suppliers must demonstrate the benefits of their products rather than just theorize what those benefits might be." ☐

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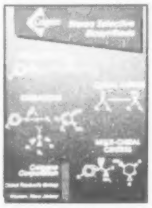

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The Life of Carl Djerassi

Reviewed by **Rudy M. Baum**

Distinguished chemist's autobiography traces a remarkable life of scientific accomplishment and social involvement

■

"The Pill, Pygmy Chimps, and Degas' Horse" by Carl Djerassi, Basic Books, 10 East 53rd St., New York, N.Y. 10022, 320 pages, **$25**

Purely on the basis of his scientific achievements, Carl Djerassi must be considered one of the preeminent organic chemists of the 20th century. In a career that has spanned almost five decades, Djerassi has been active in the development of new medicinal agents, including the synthesis of the first active oral contraceptive; the isolation, structure elucidation, and partial synthesis of several hundred natural products; and investigations into aspects of the biological function and biosynthesis of those natural products.

Perhaps most important scientifically, Djerassi has played a central role in developing several physical methods for the solution of stereochemical and structural problems in chemistry. His research has led to the publication of more than 1100 papers and seven books, which he either authored or coauthored. This year, the American Chemical Society awarded him its highest honor, the Priestley Medal, in recognition of his accomplishments.

Although many distinguished chemists make important contributions to society outside of their scientific discipline, Djerassi is unique in the breadth of those outside achievements. He has been a very successful businessman. He has written extensively on the social impacts of science and technology, especially contraceptives. He is a patron of the arts, originally as a collector, notably of the works of Paul Klee, and now as the guiding force behind the Djerassi Foundation's Resident Artists Program, a major artists' colony located on Djerassi's ranch south of San Francisco. And he is an artist in his own right, as the author of a collection of short stories, a collection of poetry, and the 1989 novel "Cantor's Dilemma."

This brimming life is the subject of Djerassi's new book, "The Pill, Pygmy Chimps, and Degas' Horse." Djerassi calls the book his nontechnical autobiography (ACS published Djerassi's chemistry autobiography, "Steroids Made It Possible," in 1990), but it's not, really, in the traditional sense of an autobiography being a narrative account of one's life. Rather, the book consists of a series of factual stories, in which Djerassi is the main character, and essays, in which Djerassi the chemist, social philosopher, and artist argues his case. In combination, these stories and essays paint their portrait in broad bright brush strokes. Djerassi approaches biography as Impressionists approached painting.

He is well aware of this, of course. He has become in the past decade an accomplished literary stylist. In the book's final chapter, "Mind the Gaps," he writes: "Everything that can be said about the self-indulgence, the deviousness, the deliberate or subliminal image massaging, of autobiographical writing has doubtless been said many times; nor is it original, I suspect, to compare autobiography and Swiss cheese. The holes in a life account may be planned or inadvertent, but they are there; self-reflection and disclosure must pass through one's particular psychic filters." But the holes, he maintains, contain vital information. "Filling the gaps in an autobiography serves no more purpose than filling the holes in Swiss cheese," he writes. "My memory, my sense of shame, and whatever residual discretion is left me guarantee that the fillers I provide are false. . . . The gaps, large as they may be, are thus more honest, a truer reflection of my nature. Freud's insight applies with full force: the unconscious speaks through the gaps in ordinary language. Readers will gather from my prose intelligence about me of which I remain unaware."

"The Pill, Pygmy Chimps, and Degas' Horse" is a delightful, fascinating, sometimes hilarious and sometimes tragic book. A reader comes away from it with the sense that he or she has spent time with a charming and interesting individual and a towering intellect. Although it is written for nonscientists, and quite successfully presents a fair amount of complex chemistry in an accessible fashion, I think scientists will most appreciate Djerassi's effort because his life is a magnified, outsized version of their own lives.

In the book's introduction Djerassi writes, "With this autobiography I want to make a point that is particularly relevant in these days of scientific illiteracy and anti-intellectualism: scientists are not necessarily narrow specialists, communicating in an incomprehensible language and dealing in the cloistered ambiance of their laboratories with subjects far removed from everyday concerns. They can be as widely curious, and as self-centeredly imperfect, as scholars and thinkers in any intellectual endeavor and, at the same time, involve themselves with burning social issues." Using himself as the principal, but by no means only, example, Djerassi convinces the reader that some scientists, at least, are today's true Renaissance women and men.

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- Du Pont and ICI agree to a swap—ICI will acquire Du Pont's U.S.-based acrylic operations, and Du Pont will take over ICI's European nylon business. Page 5
- FDA decides to limit access to silicone gel breast implants while safety studies are conducted, possibly sounding the death knell for such implants. Page 5
- NASA marks Hubble Space Telescope's second anniversary in orbit by releasing latest dramatic photos. Page 6
- Many chemical companies report better first-quarter earnings for 1992 than for first-quarter 1991, but two firms show large declines. Page 6

COVER: Freestanding glass mosaic monument, titled "Second Genesis," symbolizes man's impact on the fragility of Earth. The mosaic was created by Jerry W. Carter for the city of Ravenna, Italy

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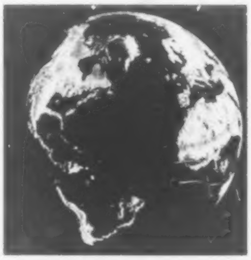

Despite global warming's complex web of interactions, experts have made progress toward a comprehensive understanding of chaotic climate system. Page 7

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Published by
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Effects of organohalogens

It is very encouraging to see the article on the effects of organohalogens on marine animals (C&EN, March 9, page 23) in relation to harm to immune systems suspected by Theo Colborn and other workers. But let us review some figures and facts about halogens and organohalogens.

Planet Earth is estimated to host 1000 billion tons of chloride in rock and 36,000 billion tons in seawater [Hopp, V., *Chem. Ztg.*, **115**, 34 (1991)]. Volcanoes expel 0.4 million to 3 million tons of hydrogen chloride per year; other workers mention 0.4 million to 11 million tons of HCl and HF [*Nature*, **334**, 415 (1988)], and it is highly likely that a fraction of this latter enormous figure is molecular halogen. Bromine can be detected from photochemical oxidation of bromide [*Nature*, **355**, 150 (1992)] and so, probably, can chlorine. And to cite V. Hopp again, "Fungi are known to release 5 million tons of chloro-organic compounds to the environment every year." For comparison, industrial production of molecular chlorine is about 35 million tons for the nondegradable polyvinyl chloride, solvents, and the like, and a fraction of 0.0074 ton for chlorofluorocarbons.

Before we jump to spectacular conclusions about organohalogens causing immune deficiency, it is worthwhile noting these numbers and looking at them from the perspective of a geological time scale. Release of funds to researchers such as Colborn and other prominent (Dutch) workers [*Science*, **255**, 798 (1992)] "to rejuvenate the bad reputations of organohalogens," provides an excellent opportunity to investigate the natural sources and cycles of chloride/chlorine/organohalogens as well.

Albert Alberts
Eindhoven, the Netherlands

High tech in Taiwan

Joseph Haggin's two articles on Taiwan's science & technology (C&EN, Feb. 3, page 21; Feb. 10, page 17) are well written and informative. However, he omitted mention of the newly established Pharmaceutical Research & Development Laboratories at the Development Center for Biotechnology (DCB-PR&D) in Taipei.

DCB-PR&D is a government-sponsored nonprofit organization with the sole objective of discovering and developing new medical entities for Taiwan's indigenous pharmaceutical companies to manufacture and sell in the global market. It epitomizes the government's determined efforts to promote high-tech and high-return industries such as pharmaceuticals.

Albert Y. Chang
Managing Director
Pharmaceutical R&D Laboratories, DCB
Taipei, Taiwan

Worldwatch Institute

The secular humanist, socialist article on Worldwatch Institute (C&EN, Jan. 20, page 18) ought to be recognized for the trash it is. A clean environment is fine, but restructuring the religious, national, and social order to get there is not.

There are a lot more important things in life that were recognized by our founding fathers—for example, "one nation under God"—that ought to come before all this environmental poppycock. In other words, the spiritual part of humans is of much more importance than the physical part.

I suggest that the squeaky clean, scraped womb society be sold an island where they can practice socialized, communal living free of phosphates, chlorofluorocarbons, incinerators, plastics, and so on to their hearts' content. And they can legislate that none of the God-worshipping kooks like myself can enter without clearance from the United Nations.

Joseph J. Guido
Hinsdale, Ill.

This is in regard to your article on Worldwatch Institute and Michael Renner's comments that the oil refining and chemical industries in the U.S. are "capital intensive, notorious users of energy, prodigious producers of pollution, and stingy users of human labor."

Tell Renner that my company—primarily engaged in oil refining and chemicals—provides almost 33,000 good-paying American jobs. Ask him how many he and his buddies provide.

Fred Brothers
Ashland Oil
Columbus, Ohio

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Chemical Industry Near Top In U.S. Trade Performance

■ ***Industry has long and consistent record of trade surpluses; among reasons are competitiveness, globalization, weak dollar***

Earl V. Anderson,
C&EN Northeast News Bureau

Like Rodney Dangerfield, the chemical industry "don't get no respect" when it comes to international trade, says Richard M. Patterson, government relations manager for Dow Chemical. Many others in the industry share his opinion, if not his simile.

It seems that whenever stories about the country's trade performance appear in the business press, the spotlight is on the persistent overall trade deficit and the poor, but improving, performance of manufactured goods in general. Last year's trade deficit in autos alone was a whopping $34.7 billion.

Plaudits, if any, go to agricultural commodities and to aircraft and aircraft parts. Based on their trade performance, agriculture and aircraft certainly deserve the praise.

But so, too, does the chemical industry. Whereas the U.S. has suffered a cumulative trade deficit of more than a trillion dollars over the past 10 years (1981–91), the chemical industry alone has chalked up a cumulative trade surplus, or net of exports over imports, of more than $126 billion. In those 10 years, it has never had a trade deficit.

Last year the chemical industry exported almost $43 billion worth of chemicals and imported $24.2 billion worth. That performance garnered it a record trade surplus of $18.8 billion, the third successive year of new highs for its trade surplus.

That chemical trade surplus is greater than the $16.3 billion surplus in agricultural commodities. And, although it can't match the $27 billion trade surplus that aircraft manufacturers achieved, the $43 billion in chemical exports handily tops the $34.7 billion worth of aircraft and parts that were exported last year.

In 1981, chemicals accounted for 9.1% of all U.S. exports. Last year, its share hit 10.2%.

All of these numbers unquestionably qualify the chemical industry for superstar status in the international trade game.

But more important than why the industry "don't get no respect" for its status is why the industry is faring so well in international trade in the first place. There is no single reason, but a combination of circumstances that has made the U.S. chemical industry one of the most competitive in the world.

A huge domestic market has made it possible for the industry, especially the petrochemical sector, to build large plants with their innate economy of scale. The flexibility of basic olefins units to use light—and less expensive—feedstocks gives olefins producers and their downstream petrochemicals customers an edge.

The industry produces more than 60,000 different products, ranging from the commodity organics and inorganics to highly specialized products. Some compete on price. For others, there simply is no reasonable substitute.

The chemical industry is a truly "global" industry, which in itself stimulates trade. "Chemicals [are] probably more globalized than any other major manufacturing industry," says Allen J. Lenz, director for trade and economics for the Chemical Manufacturers Association (CMA).

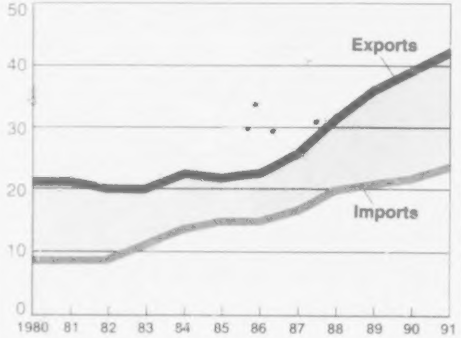
There are many other factors that affect the way the trade ball bounces—factors that are beyond the control of the chemical industry itself. Currency exchange rates are one of them. Major political upheavals—the Persian Gulf War is just one of many examples—are another.

In recent testimony on trade policy before the House Ways & Means Subcommittee on Trade, W. H. Clark Jr., head of the Office of the Chemical Industry Trade Adviser and chairman and chief executive officer of Nalco Chemical, pinpointed the role that even a country's trade laws can play. He said that, for the most part, U.S. trade laws have been eminently fair to the U.S. chemical industry, and that "we've flourished in this hospitable climate."

Most of this "flourishing" has been done by the large, U.S.-based multinational chemical companies, which traditionally have been the dominant chemical exporters. They still are, but there are signs that small and medium-sized chemical companies now are getting into the export act.

Vincent J. Kamenicky, senior chemical adviser in the Commerce Department's International Trade Administration, says that,

Chemical trade balance hits new high in 1991 as exports surge



Source: Bureau of the Census

U.S. chemical industry had record trade surplus of $18.8 billion in 1991

$ Millions	1989	1990	1991	% change 1990–91
Canada				
Exports	$4,210	$ 6,050	$ 6,555	8.3%
Imports	3,934	4,305	4,352	1.1
Trade balance	276	1,745	2,203	
European Community				
Exports	9,758	10,509	11,250	7.1
Imports	9,158	9,728	10,418	7.1
Trade balance	600	781	832	
Eastern Europe				
Exports	409	460	387	-15.9
Imports	208	242	263	8.7
Trade balance	201	218	124	
Communist Asia				
Exports	1,136	1,054	1,671	58.5
Imports	273	337	392	16.3
Trade balance	863	717	1,279	
Japan				
Exports	4,664	4,582	5,047	10.1
Imports	2,373	2,391	2,706	13.2
Trade balance	2,291	2,191	2,341	
Rest of Asia				
Exports	6,624	6,566	7,172	9.2
Imports	985	1,267	1,445	14.0
Trade balance	5,639	5,299	5,727	

$ Millions	1989	1990	1991	% change 1990–91
Middle East				
Exports	$ 543	$ 629	$ 673	7.0%
Imports	371	355	372	4.8
Trade balance	172	274	301	
Latin America				
Exports	5,419	5,773	6,590	14.2
Imports	1,671	1,287	1,333	3.6
Trade balance	3,748	4,486	5,257	
Australasia				
Exports	1,364	1,247	1,357	8.8
Imports	291	344	421	22.4
Trade balance	1,073	903	936	
Africa				
Exports	702	628	715	13.9
Imports	61	90	95	5.6
Trade balance	641	538	620	
Other				
Exports	1,656	1,485	1,550	4.4
Imports	1,427	2,122	2,372	11.8
Trade balance	229	-637	822	
TOTAL				
Exports	$36,485	$38,983	$42,967	10.2%
Imports	20,752	22,468	24,169	7.6
Trade balance	15,733	16,515	18,798	

Source: Bureau of the Census

since the mid-eighties, many small and midsize chemical companies have tested and liked the export market. These companies typically have specialty products for niche markets. "There should be tremendous export growth in these areas," says Kamenicky.

"Globalization" of the chemical industry has had a definite, if not a completely apparent, impact on U.S. chemical exports. U.S. chemical companies have invested heavily in the chemical industries of other countries. And foreign chemical companies have invested large amounts of money in the U.S. chemical industry, particularly in the past few years.

In 1988, according to the Department of Commerce, 170 U.S. chemical industry "parents" had 2867 affiliates abroad in all industries, including chemicals. Conversely, there were 1749 affiliates of foreign chemical companies in the U.S.

These complementary foreign direct investments have generated substantial trade between U.S. chemical companies and their foreign affiliates, and between U.S. affiliates and their foreign parents, says CMA's Lenz. The Commerce Department estimates that, in 1988, U.S. chemical company parents exported $10.6 billion to their foreign affiliates.

That's a hefty one third of all the chemicals ($31.9 billion) exported that year. Add to that the $4 billion that U.S. affiliates exported to their foreign parents and this two-way direct investment, this globalization of the chemical industry, as Lenz calls it, can be credited with almost half of what the U.S. chemical industry exports.

More than two thirds of the U.S. chemical industry's direct foreign investment is in Europe and Canada. And about 94% of the foreign direct investment in the U.S. chemical industry is by companies based in either Europe or Canada.

Consequently, most of the parent-affiliate trade in chemicals occurs between the U.S. and those two areas. And a very high proportion of U.S. chemical trade with those two areas is between parents and affiliates.

Exchange rates, and thus the strength or weakness of the U.S. dollar against major foreign currencies, can have a significant impact on trade performance, including that of the U.S. chemical industry. A strong dollar, for instance, makes U.S. exports more expensive—and less competitive—in foreign markets. Imports, meanwhile, become more competitive. All else being equal, the U.S. chemical trade surplus suffers when the dollar is strong.

Conversely, when the dollar is weak, U.S. exports become more competitive abroad and imports become more expensive in U.S. markets. This helps the chemical trade balance.

In the early eighties, the dollar grew much stronger. It peaked in 1984. During those years, chemical exports grew slowly or declined. Chemical imports grew much more rapidly than exports.

The U.S. chemical trade surplus dropped sharply and did not bottom out until 1985. Of course, the recession of the early eighties also influenced the chemical trade patterns of the times. But there's a strong correlation between exchange rates and chemical trade flows.

Since 1985, the dollar has generally gotten much weaker, although it did regain some of that lost strength during part of last year. Nevertheless, as the dollar weakened, U.S. chemical exports grew rapidly, far outpacing the growth in chemical imports. And, since 1986, the U.S. chemical trade surplus has increased every year, expanding two and a half times to $18.8 billion last year.

In fact, the chemical industry has chalked up trade surpluses in each of the nine major product groups by which chemical trade data are measured. By far the largest chemical trade surplus belongs to "plastics in primary form," another way of saying synthetic resins. This category had a lopsided $5.6 billion surplus last year on exports of $7.5 billion.

Other chemical categories that have large trade surpluses include organics, medicinals and pharmaceuticals, fertilizers, and the catch-all "other" category. The industry has even been able to turn around its trade in dyes, tanning, and coloring materials.

This category ran trade deficits from 1984 to 1989, reaching a high of $315 million in 1987. But in 1990, that category racked up a trade surplus of $300 million, before tapering off to $232 million last year.

Another "basket" category of chemical products that includes essential oils, perfumes, and all kinds of toiletry and cleansing preparations also ran slight trade deficits between 1986 and 1988. But these products enjoyed a huge $944 million trade surplus last year.

Not surprisingly, the bulk of U.S. chemical exports goes to other industrialized countries. Canada is the largest single export market for U.S. chemicals. It, along with the 12-nation European Community (EC), accounts for more than 40% of the total.

Although the U.S. ran chemical trade deficits with both Canada and the EC from 1984 to 1988, it has since converted them into substantial trade surpluses.

But developing country markets also are important in the U.S. chemical trade picture. Asia and Latin America, in particular, are large and growing markets for U.S. chemical exports. Last year, those two areas alone took 32% of all U.S. chemical exports. And last year, they were the fastest growing of all the major U.S. chemical export markets.

Lenz and other trade experts think that the chemical trade surplus may have peaked last year. And modest declines may be likely for the next few years as new capacity comes on stream overseas.

But even these developments will not diminish the chemical industry's luster as one of the country's strongest trade performers. ☐

Four developing nations in top 10 U.S. chemical export markets . . .

Top 10 countries		1991 U.S. chemical exports, $ millions
1	Canada	$6555
2	Japan	5047
3	Mexico	2624
4	Belgium	2367
5	Netherlands	2357
6	Germany	1911
7	Taiwan	1840
8	China	1671
9	South Korea	1658
10	U.K.	1580

. . . but only one is a major supplier of U.S. chemical imports

Top 10 countries		1991 U.S. chemical imports, $ millions
1	Canada	$4348
2	Germany	3228
3	Japan	2739
4	U.K.	2228
5	France	1573
6	Switzerland	1136
7	Italy	865
8	Mexico	700
9	Netherlands	671
10	Ireland	662

Source: Bureau of the Census

Exports of several chemical categories registered double-digit increases last year

$ Millions	1989	1990	1991	% change 1990–91
Organics				
Exports	$10,609	$10,400	$10,928	5.1%
Imports	7,042	7,392	8,157	10.3
Trade balance	3,567	3,008	2,771	
Inorganics				
Exports	4,319	3,816	4,102	7.5
Imports	3,231	3,234	3,299	2.0
Trade balance	1,088	582	803	
Dyeing, tanning & coloring materials				
Exports	1,097	1,588	1,648	3.8
Imports	1,133	1,288	1,416	9.9
Trade balance	36	300	232	
Medicinals & pharmaceuticals				
Exports	3,660	4,103	4,606	12.3
Imports	2,086	2,500	3,053	22.1
Trade balance	1,574	1,603	1,553	
Essential oils, perfumes, toiletry & cleansing preparations				
Exports	1,469	1,963	2,361	20.3
Imports	1,165	1,323	1,417	7.1
Trade balance	304	640	944	

$ Millions	1989	1990	1991	% change 1990–91
Fertilizers				
Exports	$ 2,821	$ 2,574	$ 2,980	15.8%
Imports	999	955	919	–3.8
Trade balance	1,822	1,619	2,061	
Plastics in primary form				
Exports	5,727	6,428	7,537	17.3
Imports	1,687	1,974	1,930	–2.2
Trade balance	4,040	4,454	5,607	
Plastics in nonprimary form				
Exports	2,202	2,633	2,786	5.8
Imports	1,629	1,774	1,855	4.6
Trade balance	573	859	931	
Other				
Exports	4,583	5,478	6,020	9.9
Imports	1,780	2,028	2,123	4.7
Trade balance	2,803	3,450	3,897	
TOTAL				
Exports	$36,485	$38,983	$42,967	10.2%
Imports	20,752	22,468	24,169	7.5
Trade balance	15,733	16,515	18,798	

Source: Bureau of the Census

CHEMICAL & ENGINEERING NEWS
C&EN
MAY 4, 1992

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RUBBER

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fastest growing product segment
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CHEMICAL & ENGINEERING NEWS

C&EN

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- Many chemists are among the 59 new members and 14 foreign associates elected to the National Academy of Sciences. **Page 4**
- Detection of minuscule variations in temperature across vast regions of space lends credence to the Big Bang theory of the formation of the universe. **Page 5**
- Protesters, including a host of demonstrative groups and individuals, turned Du Pont's annual meeting last week into a very lively affair. **Page 6**
- New family of fullerene-uranium endohedral complexes synthesized, including small C_{28}-uranium complex. **Page 6**

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1155—16th St., N.W., Washington, D.C. 20036

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LETTERS

The job interview

I have been reading with interest the letters concerning the poor treatment of interviewees for industrial positions. I have been exposed to this process recently during my own job search, and would like to say that during five interviews, I have been treated with dignity and respect by everyone with whom I have met.

However, I am sorry to say that the situation was quite different last fall when I applied for six academic positions at high-level research universities. I would like to relate my experiences for two reasons.

First, I wish to alert other faculty search committees to be aware of the candidate's perspective during this very difficult process. Second, I dare to suggest to those who bemoan the appalling lack of young chemists (especially women) in the pipeline that we are indeed out there; however, we may be ignored, or worse, pushed away as I was.

Of the six schools to which I applied in October 1991 for the position of assistant professor of analytical chemistry, one turned me down one month after receiving my application because they had already filled the position. From the wording of the rejection letter, I believe that the candidate was preselected and hired from the inside. I understand this occurs quite frequently, and I only wish that I had known this in advance so that I could have saved the postage.

Of the five remaining universities, two did not hire an analytical chemist at all, probably because these were open searches for assistant professors in all areas of chemistry and there seems to be an abundance of qualified candidates compared to the number of available slots.

Two other search committees still have not bothered to contact me at all after five months! The only way I know of the status of these two applications is that I called the chairman of the respective search committees and inquired. In one of the two cases, the committee had lost two of my letters of recommendation (and claimed that they had never been received) although they never attempted to contact me to this effect. As such, my file remained incomplete and I was probably never considered as a candidate. I have found this kind of treatment to be rude, insulting, and dehumanizing to the candidate who anxiously checks the mail each day hoping for some word.

The sixth school brought me in for an interview in December. My experience began with the suggestion by my host that after arriving at the airport in a large midwestern city, I should make use of the public transportation system, which would deposit me several blocks away from the chemistry building with all my luggage in hand. I refused this suggestion, and requested to take a shuttle to my hotel in order to check in prior to the beginning of my interview that same day. I accepted this alternative as no one could (or would) come to the airport to pick me up, nor would anyone come to my hotel to bring me to the interview. (By distinct contrast, I remember being treated substantially better when I was a prospective graduate student visiting the different chemistry departments.)

The rest of the interview was unremarkable until the time of the dreaded "drill session," during which the faculty members question the candidate on the merit and viability of the proposed research. My session was scheduled over a one-hour lunch period on the second day of the interview. I was ushered into the faculty lounge where deli platters awaited; I then had food practically thrown onto my plate while I was told to eat as fast as I could since I would be presenting my proposals while everyone else was enjoying their lunch. I choked down my sandwich and began my presentation. I was very soon aware that of the 10 to 15 faculty members present, only one or two had bothered to read my proposals ahead of time, although they had been included with my application. I was caught by surprise at the overall ignorance of my audience, and I then spent an inordinate amount of time outlining my ideas when I should have been underscoring their scientific merit. When it was

Letters to the Editor

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PRODUCT REPORT

Advanced Elastomer Systems photo

Thermoplastic Elastomers Bring New Vigor to Rubber Industry

Marc S. Reisch,
C&EN Northeast News Bureau

Use of traditional synthetic and natural rubber has struck a sort of balance over the past decade. Both categories of materials have shown growth in line with that of the gross national product. However, use of thermoplastic elastomers (TPEs) as direct replacements for traditional synthetic and natural rubbers is showing healthy growth, primarily because of ease of processing and fewer waste disposal problems.

For one, TPEs are more economical to produce than traditional thermoset materials, because fewer steps are required to manufacture them than to manufacture and vulcanize thermoset rubber. They are also easier to process on widely used and inexpensive plastic extrusion or injection-molding equipment, which gives faster production than slow-cycling, capital-intensive rubber processing equipment.

In addition, TPE factory scrap as well as postconsumer parts can be ground and reused. As a result, TPEs have, on the one hand, an economic advantage over traditional thermosets because the manufacturer has fewer waste disposal problems. On the other hand, their recyclability also endears them to environmental activists because the elastomers need not go into landfills or incinerators. Also, engineers can design parts using a wide range of TPEs from styrenics to high-performance polyamides. And within the individual classifications of TPEs, engineers can choose from a variety of performance criteria.

Very few TPE manufacturers would argue, however, that their product will replace all traditional rubber uses. TPEs do not have the wide temperature performance range of thermoset rubbers. In addition, their compression set, solvent resistance, and deformation resistance at high temperatures are generally not so good as those of cured thermoset elastomers. Consequently, TPEs are not used in tires. According to the International Institute of Synthetic Rubber Producers (IISRP), Houston, tire and tire products consume almost three quarters of the world's natural rubber and almost half of synthetic rubber annually.

Last year, the worldwide recession cut into demand for traditional thermoset rubber. World rubber consumption in 1991 declined almost 5% from 1990 to 14.2 million metric tons, according to IISRP. About 65% of rubber consumed in 1991 was synthetic rubber, such as styrene-butadiene or polybutadiene. Synthetic rubber demand in 1991 totaled 9.2 million metric tons, down almost 7% from 1990. Natural rubber consumption, at 5 million metric tons last year, was essentially unchanged from 1990, and made up some 35% of all rubber consumed.

IISRP regards thermoplastic elastomers as a "below-the-line" item, and does not count them in its totals for rubber. Adding IISRP's thermoplastic elastomer consumption figures to its traditional synthetic and natural rubber surveys gives a picture of a group of elastomers whose use is growing even during a world recession and whose use is projected to grow mostly at the expense of thermoset synthetic rubber. In 1991, TPE consumption rose 5% worldwide from the previous year to 707,000 metric tons. That would put TPE use at nearly 5% of worldwide elastomer consumption in 1991, with synthetic rubber at 62% and natural rubber at 33%. However, TPEs now account for 10% of all nontire uses and may grow to 12% by 1996.

IISRP projects that TPE consumption will increase to 923,000 metric tons by 1996, giving it almost 6% of the world rubber market, as opposed to 35% for natural rubber and 59% for synthetic rubber. Whereas IISRP projects TPE consumption will grow at more than 5% annually over the next five years, it forecasts world synthetic rubber consumption will rise only 1.5% annually to just under 10 million metric tons, and natural rubber consumption will increase a little more than 3% per year to almost 5.9 million metric tons in 1996.

In North America, TPEs have already taken nearly 8% of the rubber market. Without any domestic source of natural rubber, the North American market traditionally has used more synthetic rubber, and has been relatively quick to embrace TPEs, consuming nearly 40% of world production in 1991. IISRP projects the average annual growth rate in North America for TPEs at more than 7% through 1996, giving them a nearly 10% share of rubber consumption. Only ethylene-propylene and a miscellaneous category of other rubbers will grow or maintain their share of the North American market, predicts IISRP. All others—styrene-butadiene, polybutadiene, nitrile, polychloroprene, and even natural rubber—will lose market share as thermoplastic use grows. Because of TPE growth, an IISRP spokesman says the organization plans to expand its statistical program to gather more data on these elastomers. Its 51 member companies include many of the world's major TPE producers.

Howard Blum, vice president of consulting firm Chem Systems, Tarrytown, N.J., estimates the value of the global TPE market at $1.5 billion. TPE use is growing 5 to 10% a year, depending on the region of the world, he says, versus 2% annual growth for traditional thermosets. Different categories of TPEs are growing at different rates. Styrenic block copolymers, for instance, are the most widely used TPEs, with 1991 use of 295,000 metric tons in the U.S., Western Europe, and Japan, according to Blum. However, their growth rate will be closer to 5% a year between 1990 and 2000. Polyolefins, on the other hand, are gaining wider acceptance now. With 1991 demand at 189,000 metric tons, they are growing at an annual rate of about 7%. Copolyesters are among the fastest growing TPEs with an annual growth rate of over 9%. Copolyesters are the least used TPEs at present, but Chem Systems' market study, scheduled to be published this month, projects demand for copolyesters will grow from 28,000 metric tons in 1990 to 68,000 metric tons in 2000.

According to Blum, the styrenics are generally lower performing and are the lower priced materials of the TPEs. Next in performance and price are the polyolefins, then thermoplastic urethanes, and at the top of the list are the copolyesters. Fairly new on the scene are higher price-performance engineering nylon elastomers. Another class of elastomers is polyvinyl chloride blends with rubber such as nitrile. Blum says these blends may be considered TPEs if "they are not pushed too hard"—that is, if they are not stretched too far to recover to their original position. Mostly used in Japan, but not widely used elsewhere, the blends compete on the lower end of the price-performance scale, says Blum.

Within the types of TPEs, manufacturers offer a number of materials to fit a variety of performance criteria. Royal Dutch/Shell, the largest U.S. and worldwide supplier of styrenic block copolymers (SBCs), produces its Kraton SBCs in three subcategories: a styrene-butadiene-styrene used in shoe soles and as both asphalt and polymer modifiers; styrene-isoprene-styrene, mainly used as a hot-melt adhesive and pressure-sensitive adhesive; and styrene-ethylene-butadiene-styrene, a high-performance TPE that brings SBCs into the engineering realm of polymers, Blum says.

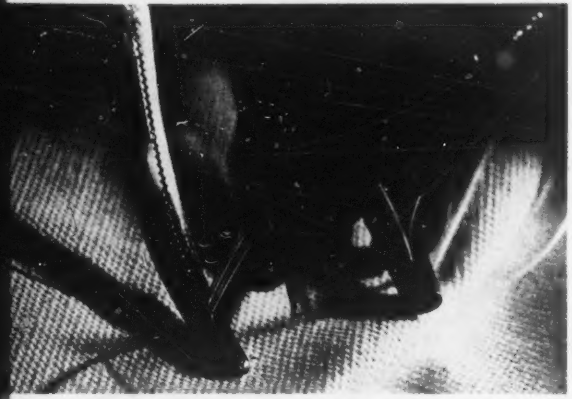
Charles P. Rader, a past chairman of the American Chemical Society's Rubber Division and a fellow in marketing and technical service for Advanced Elastomer Systems, says TPEs are "where the action is" in rubber use today. The ACS Rubber Division formed a thermoplastic elastomers group about four years ago to promote further development of them. One of the group's efforts has been to work with the Society of Automotive Engineers to set performance standards for factory regrind and recycled TPEs in automotive components.

The division's TPE group also plans a TPE symposium in November in Nashville, Tenn., says Rader. A reason

Demand for major thermoplastic elastomers to rise about 6% annually

Thousands of metric tons	1990	1991	2000	% annual change
Styrenic block copolymers	**284**	**295**	**448**	**4.7%**
U.S.	136	139	236	5.7
Western Europe	118	123	157	2.9
Japan	30	33	55	6.2
Polyolefins	**177**	**189**	**356**	**7.2%**
U.S.	75	81	196	10.1
Western Europe	80	84	126	4.6
Japan	22	24	34	3.5
Polyurethanes	**82**	**84**	**129**	**4.6%**
U.S.	30	29	44	3.9
Western Europe	42	44	69	5.1
Japan	10	11	16	4.8
Copolyesters	**28**	**30**	**68**	**9.1%**
U.S.	15	16	38	9.4
Western Europe	8	9	20	9.6
Japan	5	5	10	7.2
TOTAL	**571**	**598**	**1000**	**5.8%**

Source: Chem Systems



Thin-wall medical-grade tubing of Miles thermoplastic polyurethane is tough, flexible

for much of the interest, he says, is that use of TPEs has grown 8 to 9% annually since 1970. As a group, TPEs have replaced traditional thermosets such as styrene-butadiene rubber (SBR) and polychloroprene, he points out. Now two thirds of TPEs are direct replacements for thermosets and about another third are new uses.

Rubber processors who know the markets for elastomers have resisted the introduction of TPEs, Rader points out, because their machinery is not equipped to process thermoplastics. Plastics extruders and molders, who can easily process TPEs, do not know the rubber markets well enough to expand into elastomer production. Each, in general, has been slow to make either the investment or the effort to exploit these elastomers, he says.

But TPEs continue to see growth as they invade the traditional thermoset businesses. Bob Ackley, president of the Davis & Standard plastics extruding machinery division of Crompton & Knowles, says purchases of equipment to process TPEs "held their own during the recession," even though capital equipment purchases tend to be an up and down business depending on the economy.

And traditional thermoset rubber manufacturers are not necessarily displeased at the growth of TPEs. John R. Johnson, plastics market development manager for Uniroyal, notes the company has sold a lot of ethylene-propylene rubber (EPR) and ethylene-propylene-diene monomer (EPDM) to thermoplastic polyolefin (TPO) compounders as TPEs in some cases replace traditional thermosets. Where TPEs replace traditional EPDM (for instance, in a gasket), the EPDM incorporated into a TPE is often included at levels of 50 to 80% as opposed to 30% in a filled EPDM gasket, says Johnson.

Johnson expects good growth in EPDM and EPR both in the U.S. and Europe for use in TPEs. Uniroyal is currently heavily promoting the sale of these materials to TPO compounders supplying the automotive market in Europe. There, Johnson says, the recyclability of TPOs has helped them displace reaction-injection-molded urethane bumpers, particularly in Germany, where the push to use recyclable materials is particularly strong. Though copolyester compounds might make good bumpers, they are more expensive than TPOs. Nylon TPEs also could be used to make recyclable bumpers, but they are both expensive and unfamiliar to manufacturers for bumper use. TPOs, Johnson says, are the best low-cost alternative to urethanes. He estimates that TPOs now make up 80% of European-made auto bumpers, compared with 30% in the U.S. But U.S. autos hold more potential. He believes Ford, for instance, may convert much of its auto bumper production from reaction-injection-molded urethane to TPO by 1995.

Mike Stralkowski, marketing manager for Du Pont Elastomers, acknowledges that TPEs have been growing faster than thermosets with few exceptions. Stralkowski is in a good position to observe the competition between TPEs and thermosets because Du Pont straddles the line as a supplier of both traditional thermoset rubbers and thermoplastics. The company is the inven-

Glossary of thermoplastic elastomers

Thermoplastic elastomers—**A range of materials with properties of rubber and plastic. They are most often processed like conventional plastics in extrusion and injection-molding equipment, but have the flexural properties, tear strength, and abrasion resistance of rubber. However, thermoplastic elastomers (TPEs) generally have a serviceable temperature range of –95 to 340 °F, and are therefore not useful in very high temperature environments, a condition under which synthetic thermosets and natural latex are more suitable.**

Copolyesters—**Randomized block copolymers of polyester crystalline hard segments and amorphous glycol soft segments.**

Melt processible rubber—**Alloys of ethylene interpolymers and chlorinated polyolefins.**

Polyamides—**Combinations of rigid nylon blocks (of nylon 6, 66, 11, 12, and 612) and flexible polyether blocks. First introduced in the early 1980s, they are not as widely used as other TPEs.**

Polyolefins—**Blends of semicrystalline thermoplastic polyolefins and amorphous elastomers, often simply called TPOs. Combinations include polypropylene and copolymers with ethylene-propylene and ethylene-propylene-diene monomer elastomers. The majority of thermoplastic polyolefins are mechanically blended. TPOs may be further refined into:**

- Thermoplastic vulcanizates (TPVs)—**Mechanically compounded mixtures of polypropylene and a vulcanized rubber, such as ethylene-propylene-diene monomer.**
- Reactor-made TPOs—**Made in polypropylene copolymer reactors, these materials contain higher levels of ethylene-propylene rubber than mechanically compounded TPOs.**

Polyurethanes—**Fully reacted isocyanate block copolymers composed of either esters or ethers, depending on desired performance characteristics.**

Styrenics—**A widely used group of styrenic block copolymers that include styrene-butadiene-styrene block copolymers; styrene-isoprene-styrene block copolymers; styrene-ethylene/butylene-styrene block copolymers; and styrene-ethylene/propylene-styrene block copolymers.**

Vinyls—**Polyvinyl chloride blends with elastomers. More widely used in Japan, but gaining acceptance in other parts of the world.**

Diverse group of manufacturers supply thermoplastic elastomers

	Styrenic block copolymers		Polyolefins		Polyurethanes		Copolyesters	
A. Schulman			■	■	■	■		
Advanced Elastomer			■	■				
Asahi Chemical	■							
BASF					■	■		
B. F. Goodrich					■	■		
BP			■					
Bayer/Miles/Polysar			■		■	■		
D&S Plastics			■					
DIC					■			
DSM			■				■	
Dainichi Seika					■			
Dexco	■							
Dow Chemical					■	■		
Du Pont							■	■
Du Pont/Toray							■	
Eastman							■	
EniChem	■							
Ferro			■					
Firestone	■							
General Electric							■	
Himont			■	■				
Hoechst			■				■	
Hüls			■					
ICI			■					
Japan Miractran					■			
Kuraray	■							
Mitsubishi Petrochemical			■					
Mitsui			■					
Monsanto Japan			■					
Morton International					■			
Nippon Elastomer	■							
Nippon Petrochemical			■					
Nippon Zeon	■							
Petrofina	■							
Repsol	■							
Royal Dutch/Shell	■	■						
Shell-JSR	■							
Showa Denko			■					
Sumitomo Chemical			■					
Sunprene			■					
Takeda Badish					■			
Technor Apex	■		■					
Tonen Kagaku			■					
Toyobo							■	

■ **U.S.** ■ **Western Europe** ■ **Japan**

Sources: Chem Systems, company data

tor and major supplier of thermoset Neoprene (polychloroprene), and offers other thermosets such as ethylene acrylic elastomer and EPDM. It also supplies TPEs—Hytrel, a copolyester; Alcryn, a melt-processible rubber; and Zytel FN, a flexible nylon. In addition, Du Pont supplies intermediates that other manufacturers use to produce polyurethane TPEs.

The few exceptions in which use of thermosets is growing as well as that of TPEs involve specialty thermosets such as Viton fluoroelastomers, Vamac ethylene acrylic elastomers, and Acsium alkylated chlorosulfonated polyethylene, says Stralkowski. Both TPEs and thermosets have their place, he asserts. On a cost-per-pound basis, thermosets tend to be less expensive because they can be loaded with additives, such as carbon black. From a performance standpoint, they offer overall better resilience, compression set, and do not creep.

Offsetting these advantages, however, is that manufacturers of thermoplastic parts can make these parts in one-step extrusion or molding processes to finer engineering tolerances. Thermoset materials, however, must be mixed, and the parts extruded and then vulcanized. The multistep manufacturing process adds time and cost to parts manufacturing. In addition, says Stralkowski, thermoplastic scrap can be recycled into new parts. Thermosets cannot be recycled. Use of thermoplastics limits waste and saves manufacturers the disposal cost of unrecyclable thermoset materials.

Du Pont's copolyester TPE Hytrel competes against its own Neoprene polychloroprene for use in automotive drive boots. Like polychloroprene, the copolyester will not break, stretch, or creep after continued flexing, says Stralkowski. Hytrel's use in drive boots is "an example of a high-performance thermoplastic penetrating the thermoset market," he says. Hytrel's dynamic properties make it a candidate for use in some belt applications and hydraulic hose. Its stability in environments where temperatures reach 300 °F also makes it a candidate for under-the-hood auto applications, unlike most other TPEs, Stralkowski says.

A change in automotive air-conditioning technology is also providing an opportunity for use of Du Pont's Xytel FN nylon TPE in air-conditioning hose. If thermoset rubber hose is used, the new hydrofluorocarbon refrigerant that will replace the chlorinated fluorocarbons now in use would leak. The new refrigerant systems will be in place next year. Stralkowski says Du Pont's Xytel FN is a candidate to form the inner layer of the hose holding the new refrigerant, whereas the outer layer will most likely remain a thermoset chlorobutyl rubber.

Global use of synthetic rubber to rise only 1.5% annually . . .

Thousands of metric tons	1991	1992	1996	% annual average growth 1991–96
Synthetic rubber[a]				
North America	2399	2484	2744	2.7%
Western Europe	2050	2068	2236	2.7
Asia & Oceania	1802	1851	2063	2.8
Latin America	553	586	638	2.9
Central Europe & former U.S.S.R.	1917	1649	1593	–3.6
Middle East & Africa	127	125	139	1.8
China/Asia	403	427	539	6.0
TOTAL	**9251**	**9190**	**9952**	**1.5%**

. . . while that of natural rubber to increase 3.3%

Thousands of metric tons	1991	1992	1996	% annual average growth 1991–96
Natural rubber[b]				
North America	846	889	987	3.1%
Western Europe	940	940	1020	1.6
Asia & Oceania	1955	1988	2281	3.1
Latin America	271	280	300	2.1
Central Europe & former U.S.S.R.	150	150	200	5.9
Middle East & Africa	165	170	190	2.9
China/Asia	668	708	894	6.0
TOTAL	**4995**	**5125**	**5872**	**3.3%**

a Excludes thermoplastic elastomers. b Excludes consumption by producing countries. **Source:** International Institute of Synthetic Rubber Producers

Bob Liskiewicz, markets and products director for Advanced Elastomer Systems (AES), the year-old $120 million Monsanto-Exxon joint venture, says the potential market for thermoplastic elastomers is about 3 million to 3.5 million metric tons annually, excluding the former Soviet bloc and China. But TPEs now have less than 10% of that market.

Developing markets for these elastomers is a time-consuming job, says Liskiewicz. Before they can replace synthetic rubber, for instance, a TPE manufacturer must show that a new TPE part would have properties equal to or better than the part it replaces. Automotive rubber parts are a major developing market for these elastomers, he says, where applications include auto air ducts, engine mounts, or rack and pinion steering linkage boots. Other potential markets for TPEs include electric tool housings, caster wheel treads, and handle grips, as well as dishwasher and washing machine parts.

Santoprene, a polyolefin thermoplastic vulcanizate, is AES's best-known product. AES compounds fully vulcanized EPDM with a polyolefin in a patented process to form Santoprene. The EPDM gives Santoprene its environmental and fluid resistance, says Liskiewicz, whereas the polyolefin component lends Santoprene easy plastics processing characteristics. Santoprene is an ideal replacement in many cases for polychloroprene and EPDM, he adds.

Santoprene's major advantage, as well as that of AES's other TPEs, such as Geolast, Trefsin, and Vistaflex, is that it processes so easily compared with rubber. "The advantage of a TPE is not the price, but the ease of processing," says Liskiewicz. If material prices were the only concern, "you would always go to rubber." The difference, he says, "is in processing time, which takes seconds for TPEs versus minutes for a comparable rubber part."

Because a number of rubber processors view TPEs as threats to their business, AES targets the product manufacturer to specify TPE parts, Liskiewicz says. Once a product manufacturer specifies a TPE part, a rubber processor may decide to take the plunge into TPE parts manufacture or it may end up losing the business to a plastics processor.

As patents on Santoprene expire and the competition in thermoplastic polyolefin vulcanizates (TPVs) heats up, Liskiewicz says AES hopes to become a leader in developing new applications for its TPE. For one, a design center in Akron, Ohio, will continue to assist customers in automotive, medical, and construction markets to develop new products. "We are dealing on an engineered level to compete with 'me-too' drop-ins," he says. Liskiewicz also sees good opportunities for TPVs in expansion joints on bridges and highways, and AES is working on specifications to develop performance criteria for TPE expansion joints.

John D. Cowperthwait, market development manager for Himont Advanced Materials, claims the company's Hifax polyolefin TPEs perform like Santoprene, but have better heat-aging characteristics and cost less than the AES product. Himont's TPEs are based on EPR and polypropylene, and as a result show good heat aging and chemical resistant characteristics, says Cowperthwait. In automotive applications, Himont's TPEs are used in shock absorber strut boots, air intake ducts, and as wire and cable coatings where they have replaced cross-linked polyethylene, he says. In addition, its TPEs are used in auto fascia and body side molding.

A new family of reactor-made cross-linked polyolefin TPEs is just now commercially available, says Cowperthwait, though the new Hifax XL line is still in the development phase and the full line is not yet available for sale. The reactor-made material incorporates more EPR in the polypropylene relative to other polyolefin TPEs. An advantage of reactor-made polyolefin TPEs is their improved consistency.

Cowperthwait says that TPEs have done a fairly good job of replacing thermoset rubber in many applications, but only after TPE resin manufacturers put a great deal of effort into developing the market. When TPEs were first introduced, he was employed at Du Pont, which was then trying to introduce its Hytrel copolyester TPE to the rubber industry. Du Pont found that traditional thermoset rubber processors felt threatened by TPEs because they "antiquated" the rubber processors' equipment.

In addition, says Cowperthwait, most automakers only know what they expect rubber parts to do—to seal; to absorb energy, vibration, or noise; and to flex. But, he stresses, they don't know the specific performance characteristics of a particular rubber type, and so rely on the supplier to provide a part that will perform to their specifications. If an automaker's requirements specify fine engineering tolerances and recyclability, then the thermoset rubber parts processor will not be able to supply such a product.

Thus, to deliver a specified part, rubber processors have to make major investments in new equipment and possibly retire existing equipment. Even today, TPEs have only a few avid supporters among parts suppliers in the automotive market with a "knowledge base" sufficiently large to promote them, says Cowperthwait. They include some traditional rubber parts suppliers who realized they must develop TPE processing capability or slowly lose business, and some plastics parts suppliers who have recognized the potential and have taken the time to learn the rubber market, he says.

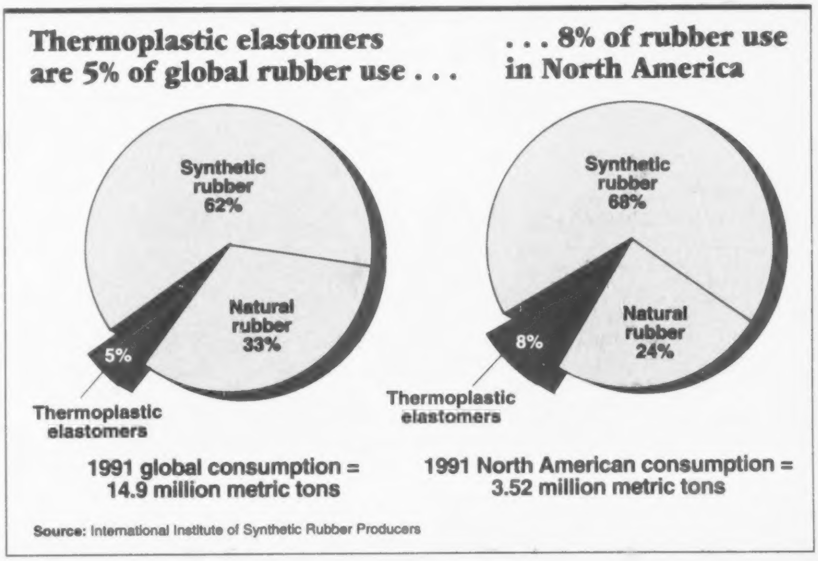
Although the recyclability of TPEs is often a selling point, Cowperthwait notes that the recyclability of postconsumer TPE materials is a matter European automakers pay more attention to than their American counterparts. Himont, in fact, recovers auto bumpers in Europe, which it regrinds and blends with virgin resins for resale under the tradename Refax. "There is no press in Detroit for recycling, unlike Europe, where car manufacturers such as BMW say they will not add more plastics to the cars they build until they figure out how to recycle the plastics," Cowperthwait says. In the U.S., he notes, current concern is more for recycling packaging materials.

Ferro's technology specialist, Paula M. Mokay, says the company has developed and recently introduced a new polypropylene TPE alloy that can be easily painted. Unlike other polyolefin TPEs that require surface treatment before painting, Ferro's new material can be made inherently polar and thus requires no primers or adhesion promoters before painting. Price is in the same range as conventional polyolefins. Mokay believes Ferro's as-yet-unnamed TPE will displace some TPVs and other TPEs now used in auto interior and exterior trim applications.

Hüls America's specialty polymers division produces a polyolefin TPV under the tradename Vestoprene. Roger W. Cash, specialty rubber marketing manager, characterizes Vestoprene as a Santoprene-type material. It is currently produced in Europe and is now available in the U.S. Cash says that Hüls is putting its R&D muscle into expanding applications and performance characteristics of its Vestoprene line to place it in markets other than the auto interior component and wire and cable coatings businesses it now competes in. Cash says Hüls is looking into a possible alliance with a domestic U.S. compounder who could make Vestoprene locally under a tolling arrangement. In addition, the company sells EPDM to U.S. TPE manufacturers.

Fabric used in Envirogear shelter consists of layers of nylon and Dow Pellethane polyurethane thermoplastic elastomer

A number of compounders are also involved in the TPE market. They include A. Schulman, of Akron, Ohio, and Technor Apex of Pawtucket, R.I. According to Alain Adam, vice president and automotive markets manager of A. Schulman, the company supplies polypropylene and EPDM-TPE blends under the Polytrope tradename for use as fascia, bumper covers, and body



Thermoplastic elastomers are 5% of global rubber use . . .

. . . 8% of rubber use in North America

1991 global consumption = 14.9 million metric tons

1991 North American consumption = 3.52 million metric tons

Source: International Institute of Synthetic Rubber Producers

Shell is latest to expand thermoplastic elastomers

With some markets growing "comfortably at double-digit rates," Anglo-Dutch chemicals giant Royal Dutch/Shell has committed nearly $115 million on a new plant for thermoplastic elastomers.

The plant, announced late last month, will be located at the company's chemicals complex at Berre, near Marseille, on the south coast of France. It will be the first commercial production by Shell outside the U.S. of its hydrogenated styrenic thermoplastic elastomers, sold under the Kraton G tradename. They are block copolymers of styrene with ethylene and butylene, or ethylene and propylene.

Shell has two other Kraton G plants, both in Belpre, Ohio, with combined capacity of 40,000 metric tons per year, currently being expanded to 45,000 metric tons. The Berre plant, scheduled to begin operating in early 1994, also will be able to produce Shellvis elastomeric viscosity index improvers, and a range of developmental thermoplastic elastomer products; total capacity will be more than 20,000 metric tons per year of product.

Shell's hydrogenated styrene elastomers are the "specialty" little brother of the company's other styrene block copolymers, sold under the Kraton D tradename in the U.S. and the Cariflex tradename in Europe. Total capacity for Kraton D—copolymers of styrene with butadiene or isoprene—is on its way to 280,000 metric tons per year: in the U.S., 80,000 metric tons at Belpre, now undergoing debottlenecking; 35,000 metric tons at Berre, being expanded to 60,000 metric tons; another 55,000 metric tons in the company's 50-50 joint venture with BASF, Rheinische Olefinwerke, at Wesseling, Germany; and 20,000 metric tons in Kashima, Japan, at Shell JSR Elastomers, the 50-50 joint venture of Shell and Japan Synthetic Rubber Co. In total, Shell claims to have more than 50% of the world market for thermoplastic elastomers.

As the sole producer of the hydrogenated elastomers, Shell is somewhat loathe to talk specifics about market sizes and growth. But company officials do point out that per capita consumption in Europe is only about one third that in the U.S. The specialty elastomers were introduced in Europe in about the mid-1980s, after being developed and marketed in the U.S. since the mid-1970s. Main end uses include adhesives and coatings, polymer modification, and in compounded form, a wide range of molded and extruded products.

"We think the market in Europe offers the same potential as that in the U.S.," says Peter E. Boorman, business manager for elastomers with Shell International Chemical Co., in London. The end uses in Europe are showing faster growth—some applications growing at double-digit rates—than in the U.S., albeit from a smaller base. "The expansions and the new capacity will be eaten up by the end of this decade," he predicts.

When the Berre plant starts up, he adds, it will join Belpre in supplying customers around the world. Given the fast growth of other consumer economies, will there be room for another Kraton G plant in Asia—in Japan, for example? "One of these days, that will be a good idea," says Boorman. "But there are absolutely no plans right now. We're going one at a time—this investment will supply demand for some time."

Patricia Layman

side molding. New grades of Polytrope will have a low coefficient of expansion for use in door side cladding so that extreme weather changes will not affect the fit of moldings. The company also supplies thermoplastic urethanes, obtaining the urethanes from Dow and filling or modifying them to customer specifications, says Adam. Priced at a premium compared with TPOs, the thermoplastic urethanes are easy to mold, have a very low coefficient of expansion, and paint easily without primer, says Adam.

Schulman also has a joint venture with Japanese compounder Mitsubishi Kasei, called Sunprene. The venture produces a mechanical blend of polyvinyl chloride and fillers to make what Adam calls a true PVC elastomer. Priced from $1.10 to $1.20 per lb, the PVC elastomers are supplied to parts suppliers of Japanese automakers with assembly operations in the U.S., says Adam. Sunprene goes after EPDM rubber applications such as weather seals and windshield reveal moldings.

Compounder Technor Apex is also producing what it calls PVC-TPEs under its own Ultraprene tradename. The Japanese have been most involved in PVC elastomers, says Lewis P. Green, plastics division marketing manager for Technor Apex. Only now are other manufacturers taking an interest in PVC, he says. In addition to PVC, Technor Apex sells specialty custom TPOs, TPVs, and SBCs. The company bought B. F. Goodrich's Telcar line of TPOs in 1980. It also produces SBCs made under license with Shell's Kraton polymers and sold under the Techron tradename for automotive dust covers, seals, trim, and knobs.

According to General Electric's applications technology engineer, Robert B. Johnson, the company's copolyester Lomod TPE covers the gap between low-end traditional rubbers and high-end thermoplastics. Lomod offers primerless paintability and better heat resistance than TPOs, he says. Lomod is aimed at five principal markets: sporting and consumer goods with a "soft touch" version, hose and tubing, sound and vibration dampers, flame-retardant enclosure applications, and auto fascias.

Although GE hopes to develop a large market for its copolyester in the automotive market by displacing TPOs, its high-gravity mineral-filled version of Lomod promises to replace metal in speaker enclosures. Johnson says Lomod has excellent sound and vibration damping abilities. Its use in speaker enclosures would displace metal or glass fiber now used there.

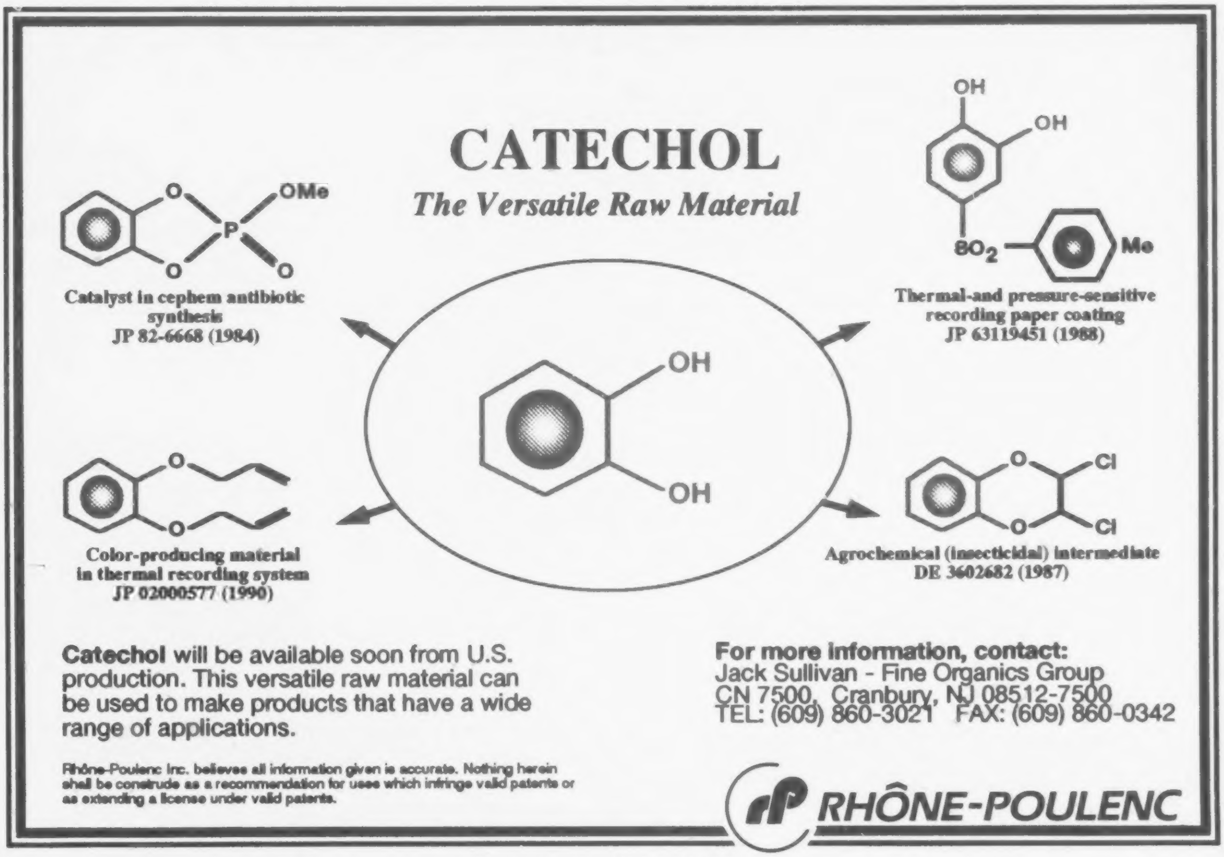
Like GE with Lomod and Du Pont with its Hytrel, Eastman also produces a copolyester TPE. Ecdel is aimed at medical applications, says Wayne Ladd, medical packaging business manager. Its principal niche is in use for drug packaging where less costly PVC packaging and its plasticizers could react with a drug and where the cost of the drug could support the higher price for Ecdel.

Dow Chemical's polyurethane TPE, Pellethane, is poised for moderate growth says Stan Nerderman, Dow Plastics product manager. It is available in ester or ether versions depending on whether chemical resistance or hydrolytic stability is of more importance, he says. Its flexibility, low-temperature impact resistance, abrasion resistance, and paintability without a primer make it useful in industrial seals, gaskets, hose, auto body side moldings, and medical tube applications. Because it is at the high end of the price-performance curve, annual growth higher than 3% may not be possible. If, however, a good case can be made for polyurethanes in a volume use such as automotive side moldings, then polyurethane applications could grow at a much faster rate, says Nerderman.

Auto axle boot of AES's Santoprene TPE outlast boots made from other rubbers

A significant Dow competitor with a series of its own polyurethane TPEs is Miles' Texin urethane TPEs. Uses for Miles' (formerly Mobay) materials include automotive suspension system parts, medical tubing, cable jacketing, seals, and even horseshoes.

Elf-Atochem manufactures what it calls an engineering-grade TPE, Pebax. It is a nylon TPE similar to Du Pont's Xytel FN. Daryl G. Davis, product manager for Elf-Atochem, says Pebax is a versatile TPE that can incorporate a variety of polyamides (6, 66, 11, 12) and different polyethers to influence the performance characteristics of different Pebax grades. The material can be hydrophilic or antistatic, for instance, and



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CIRCLE 14 ON READER SERVICE CARD

Bumper fascias on 1992 Pontiac Bonneville SSEi are molded of General Electric's Lomod copolyester thermoplastic elastomer offer heat resistance and paintability

gives service in temperature ranges between -40 and 80 °C. Medical applications include catheters, tubing, and film for transdermal patches and wound covers. Sports applications include athletic shoe soles and swim fins, and industrial uses include conveyor belts and bushings for shock absorption. Pebax, Davis says, is lighter than copolyester TPEs and competes with them as well as polyurethane TPEs. He believes demand for Pebax will grow 15 to 20% annually for the next several years.

Pebax, says Davis, has been available for the past 10 years in both Europe and North America. Its use in North America has increased dramatically in the past three years, he says. Elf-Atochem manufactures most grades of Pebax at a plant in Pennsylvania for the North American market, but imports some grades from plants in Europe. Users will specify a material such as Pebax, which is priced at the high end of the TPE market, because they want a high-performance material and are willing to pay the premium, he says.

Davis, like other marketers of TPEs, does not believe that TPEs will replace thermoset rubbers entirely either now or in the future. They are all confident, however, that TPE use will grow, most often at the expense of thermosets. Although TPEs have processing advantages over traditional thermoset products, their performance temperature ranges still restrict them from the major rubber market—car and truck tires. But where their recyclability and performance criteria satisfy specific market needs, their use will grow. TPEs, after all, are currently the most dynamic rubber market. ☐

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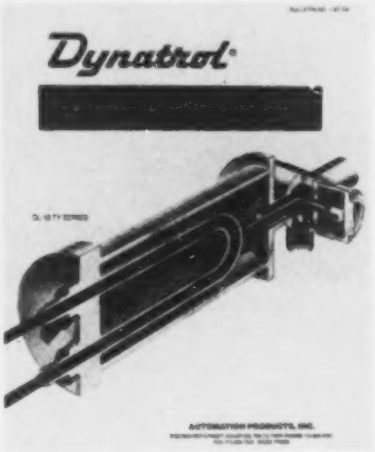

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CIRCLE 29 ON READER SERVICE CARD

Marriage, Gender Influence Career Advancement for Chemists

■ ***Many married women compromise on their careers, either for family or because their gender hinders promotion***

Mairin Brennan, C&EN Washington

The results of a new survey by the American Chemical Society that examines the influence of family responsibilities and gender on career advancement suggest that compromise is the lot of dual-career families, especially those with children. And women do most of the compromising.

The survey uncovers some striking patterns: Among chemical professionals, married women are more likely than married men to view their spouse's career as more important than their own; married women are less likely than all other categories of chemists to rate financial necessity as important in a career; married women with children are the most likely to work part-time; and married women are more likely than married men to relocate for a spouse's career.

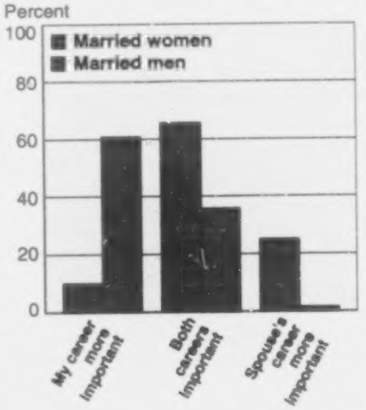
The survey also clearly shows that the issues of sex discrimination and sexual harassment are far from being laid to rest: Nearly half the women surveyed perceive gender as a roadblock to career advancement, and nearly 40% say they have encountered sexual harassment in the workplace, against themselves or against other women.

The survey was mailed last fall to 4200 chemists (2100 of each gender), selected on the basis of age and type of employer. Responses totaled 2851 (68%), with more women (72%) than men (64%) responding. The survey was prompted by ACS's analysis of its 1990 annual survey of the salary and employment of its members, which showed the same salary pattern as had existed 15 years before, when the society began its every-five-year analyses that monitor the status of women (C&EN, Oct. 21, 1991, page 31). To wit, starting salaries were about the same for both sexes, but women's salaries overall slid with years of experience compared with men's.

At the same time, the number of women entering chemistry continued to escalate—women earned 39% of B.S. and 25% of Ph.D. degrees in 1989 (the latest year for which statistical data are available) compared with 18% and 8%, respectively, in 1970. And women were moving into industrial employment in nearly the same proportion as men (63% of women versus 64% of men last year).

Despite these numerical gains, however, women have not made comparable inroads into management and the higher academic ranks. In 1975, 13% of Ph.D. women chemists in industry were in R&D management; in 1991 that figure dipped to 12%. In academia, 24% of Ph.D. women chemists were full professors in 1980 (rank was not asked in 1975); by 1991 this proportion had barely edged up (25%). Salaries, however, are nearly identical for men and women with the same length of experience doing the same work—for example, among Ph.D. industrial chemists in applied research, women's salaries are 98 to 100% of men's through 24 years following the B.S. degree. So the salary gap with years of experience seems related to differences in job function.

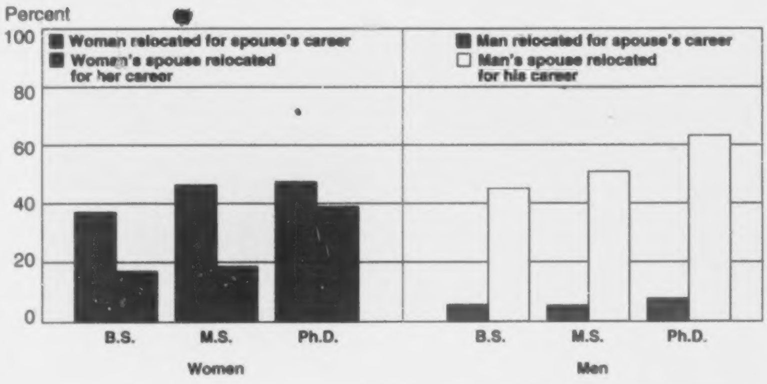
A fourth of married women put spouse's career first



In the new survey, 89% of respondents were either married (77%) or living with a partner (12%). Women and men from 20 to 34 years old (the youngest age group surveyed) were about equally likely to be married (61% versus 64%); but above age 34, women were less likely than men to be married—68% of women versus 85% of men who were 35 to 49 years of age (the middle age group) and 59% versus 87% of those who were 50 to 64 years old (the older age group). Also above age 34, women were less likely than men to have children—63% versus 80% in the middle age group and 64% versus 92% in the older age group, suggesting that many of these women may have found marriage and/or children incompatible with a career. (In the younger age group, only 29% of women and 33% of men have children. These chemists, in the very early years of a career, may want to establish a career before having children.)

The majority of women in the survey (58%) were employed in industry, followed by 11% in government, 10% in non-Ph.D.-granting institutions, 9% in Ph.D.-granting institutions, and the remainder scattered among high schools, medical schools, and other places of employment. Men were spread nearly equally by employment: 60% in industry, 10% in government, 11% in Ph.D.-granting institutions, 9% in non-Ph.D.-granting institutions, and the remainder elsewhere.

Most married men (88%) and married women (82%) were supportive of their spouse's career. However, 61% of the men but only 10% of the women said their career was more important than their spouse's. Moreover, 25% of



Only women Ph.D.s and their spouses relocate nearly equally for each other's career

the women versus just 2% of the men deemed their spouse's career more important than their own. (The remainder held both careers equally important.)

Another gender difference that came to light is willingness to relocate to benefit a partner's career. Forty-four percent of the women, but only 7% of the men, said they had relocated to accommodate their spouses. Conversely, 59% of the men said their spouses had relocated for the sake of the man's career, whereas only 27% of the women claimed their spouses relocated for them. However, 32% of all men said their spouses were not in paid employment (only 7% of women said this) so, for some men, relocating very likely did not impinge on a spouse's career. Ph.D. chemists relocated more often than chemists with lesser degrees, and Ph.D. women chemists were more likely than other women to have their spouses relocate for them. Both men and women who relocated for the benefit of a partner had fewer job applications, job interviews, and job offers before accepting their most recent job than those who did not relocate for a spouse.

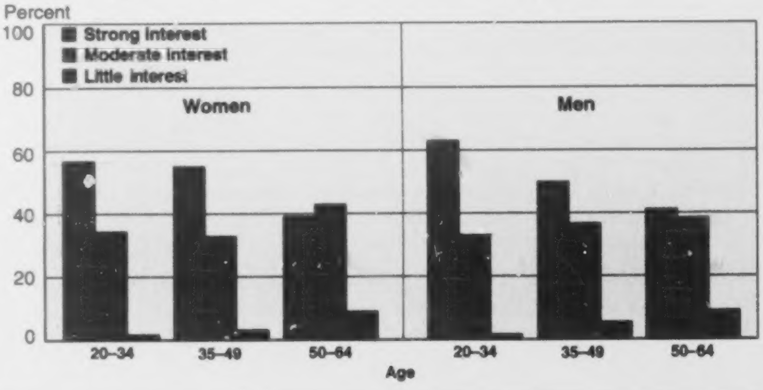
Compared with all other chemists, married women with children were less likely to be working full-time (82%) and more likely to be working part-time (11%). Overall, 89% of women worked full-time, including 98% of single women with children, 93% of single women, and 91% of married women without children. By comparison, 95% of men worked full-time, totaling 100% of single men with children, 98% of married men with children, 92% of married men with no children, and 91% of single men.

The survey found that interest in career was little influenced by degree, employer, gender, or family responsibilities. Instead, it was age-dependent, with younger chemists expressing the most interest. Respondents overall were committed to their careers—only 6% professed little or no interest, and, even among older chemists, more than 80% reported moderate to strong interest. It's noteworthy that 27% of women and 22% of men placed family or quality of life before career. Respondents didn't differ significantly in their perception of whether gender influences one's prospect of getting a job—53% of women and 55% of men believed gender has no effect. But some women (18%) and men (14%) believed their own sex to be an advantage, and 11% of women versus 5% of men believed it to be a disadvantage. Both men and women with primary responsibility for child care reported fewer job applications and job offers. Possibly these chemists narrowed their job search to positions they believed compatible with family responsibilities, or they lacked mobility, or both. Seventy-nine percent of women and 91% of men said training opportunities on the job are the same for men and women—but 20% of women and 5% of men said they are better for men.

When it comes to climbing the career ladder, however, only 47% of women and 73% of men said gender makes no difference. Here the same proportion of women (47%) and 19% of men said gender plays a role. The larger the size of the employer, the larger the proportion of women who believed this to be true. For example, 59% of women working for employers having 25,000 or more employees shared this opinion, compared with 24% of women working for employers having 50 or less employees.

When asked, "Have you encountered any instances of sex discrimination at work?" only 41% of the women, compared with 70% of the men, said they hadn't. And 43% of women and 13% of men said they had encountered sex discrimination to the advantage of men.

Women were also more likely than men to say they had encountered sexual harassment at work. Only 51% of the women, compared with 80% of the men, said they had experienced no instances of sexual harassment. A third of the women (34%) said they had experienced sexual harassment against themselves and 38% said they had observed it against other women. Nearly a fifth of the men (19%) said they were aware of sexual harassment against



Age, not gender, affects interest in career progression women. (Only 3% of either sex said they had encountered sexual harassment against men.)

The survey also asked respondents how much extended leave they had taken for family reasons: 28% of women and 22% of men had availed of such leave. Of those who had, 77% of the women and 7% of the men cited child care as the reason. Women in all age groups had taken leave for child care, and the proportion of younger women who availed of this leave was only slightly more than in the other age groups. All of the men who took leave for child care were 34 or younger, no doubt reflecting the growing trend toward shared child care in dual-career families.

Leave time ranged from one month to eight years or more, with men and women in the younger age group more likely to have taken less time off—70% of these women and 67% of the men took six months or less. This fits with the times—young chemists in dual-career families are more likely to abbreviate their leave so as not to interrupt their careers. By comparison, nearly half (48%) of the older age women took three years or more of leave time, with 22% taking eight years or more, reflecting the tradition of the past, when the woman was more likely to be the homemaker. However, older women are more likely than younger women to have had several children, which also could account for their having taken more leave.

The survey also looked for distribution of employee benefits—flextime, sick leave, maternity and paternity leave, child care facilities, and others—among employers, and their impact on respondents. It found that with the exception of flextime, the larger the size of the employer the more likely a benefit would be offered and the more likely paid rather than unpaid leave would be offered. Sick leave was a more or less universal benefit—only 3% of respondents, some of whom could be self-employed, said they had no sick leave benefits.

But employers overall weren't so generous with maternity leave, and were far less generous with paternity leave. Only 57% of respondents who worked for the largest size employers (25,000 or more employees) said their employer offered paid maternity leave. And 26% of respondents who worked for employers of 50 or fewer people said no maternity benefits were offered. A scant 7% of respondents said their employer provided paid paternity leave, and only 19% said unpaid paternity leave was offered.

The ACS survey follows a similar survey of some 2600 British chemists conducted by the Royal Society of Chemistry in 1988 (C&EN, Oct. 21, 1991, page 31), and although there are some variations, the same trends are generally evident in both surveys. For example, in both the U.S. and the U.K., women are more likely than men to perceive sex discrimination and sexual harassment in the workplace, but American women are more likely than British women to say they have encountered either. And British men are more likely than American men to believe their sex an advantage for promotion.

As in the U.S., there was a large gender gap in how married British chemists rated the importance of their careers relative to their spouse's and in how they rated the importance of financial necessity to a career. Similarly, most British chemists considered training opportunities at work to be equal for both sexes, but gender was seen to influence promotion.

The results of both surveys seem to show that despite a strong interest in their careers, many married women are subordinating their careers to those of their spouses. Lower financial pressure, the desire for quality family life, and the demands of child rearing are arguments for compromise (although not exclusively on the part of the women). However, to the extent that gender influences promotion and curtails achievement, women are forced to compromise.

There's no neat formula for how to balance careers in dual-income families. As long as the prime child-bearing years coincide with the years in which careers are built, conflict, compromise, and hard choices are unavoidable. However, the ACS survey suggests that men are taking steps toward equity in sharing responsibilities, and that

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The Center will host the Second Annual Biocatalysis and Bioprocessing Conference in Iowa City on October 25–26, 1992. Industrial participants are invited to join us for a fall football weekend and to present a poster on biocatalysis/bioprocessing research. Information about the Center for Biocatalysis and Bioprocessing and the October conference is available from:

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CIRCLE 20 ON READER SERVICE CARD

some employers are attempting to ease the way: Younger men have begun to take extended leave for child care, paternity leave has surfaced, and a number of men are relocating for the sake of their spouse's career.

A full report on the "1991 Survey of Domestic Status, Employment, and Attitudes of Men & Women ACS Members" will be issued by the ACS Office of Professional Services this summer. □

CAS cuts prices further for on-line database use

Chemical Abstracts Service will take another step in its shift away from time-based charging for use of its on-line databases on June 1. At that time, connect-hour charges for all CAS files on STN International, except learning files, will be lowered to $29. Connect-hour charges for the affected files currently are as high as $72. CAS lowered the connect-hour charge for the learning files to $15 earlier this year.

CAS began a shift away from time-based charging in 1988, placing greater emphasis on charges for the number of terms used in a search statement and answers displayed. In the June 1 price shift, search-term and time charges will be adjusted so that, allowing for the effect of system and file enhancements, the same searching patterns in CAS files on STN will yield about the same revenue to CAS. The new search-term charges will range from 45 cents in the CApreviews file to $2.85 in the Registry file. Charges for answer displays are not being changed.

Along with the price shift, CAS will introduce changes in its Registry file that will improve searching efficiency and searching speed for chemical names, classes of substances, and ring systems. Response time for all CAS files on STN International has been improved over the past six months and will be improved more in June. As a result of the system and pricing changes, the cost of any given search is likely to change—upward or downward.

James V. Seals Jr., director of marketing and corporate development for CAS, says CAS believes the price of an on-line search should reflect the value of the search to the user, not the length of time the user is connected to the host computer, which can vary greatly according to the speed of the user's equipment, the particular on-line service accessed, the particular database searched, and the time of day the search is made. "Our price shift is meant to place the charges where the value is—on the content, quality, and organization of the database, which are the result of the database producer's editorial processes," Seals says.

Largely because of connect-time pricing of on-line searches, Seals points out, many techniques and much technology have evolved to minimize the time a searcher is connected to a database to conduct a search. The response of most on-line service operators and database producers to these developments has been to increase connect-hour charges to compensate for the decreasing time the searcher is connected to the database. Seals says the very high connect-time charges that have resulted place the highest charges on a parameter that has no relationship at all to the value of the on-line search and discourage users from making full use of the interactive capabilities of on-line searching by pressuring them to minimize the time they are connected to a database.

"We believe that the lower connect-hour charges will enable searchers to browse in files, test their queries, review potential answers, and reformulate their search strategies at a thoughtful pace," Seals says. "We believe that by doing so, they will realize a much greater value for their on-line searching dollar." □

Fellowships available in solid-state chemistry

Corporate Research Laboratories of Exxon Research & Engineering Co. is continuing its sponsorship of a $7000 fellowship in solid-state chemistry. Selection of the fellowship recipient is administered by the Solid-State Subdivision of the ACS Division of Inorganic Chemistry. The fellowship will be presented at the 1992 fall ACS national meeting, and includes up to $500 to assist with the recipient's travel expenses.

The recipient of the fellowship must hold a tenure-track faculty position at an American university and not be more than six years beyond the Ph.D. degree at the closing date for nominations. The purpose of the grant is to support solid-state chemistry as a recognized discipline and to encourage

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TOP 100

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CHEMICAL & ENGINEERING NEWS
C&EN
MAY 11, 1992

NEWS OF THE WEEK

- Metal-carbon clusters appear to increase in size by forming multiple, linked cages, as shown by mass spectra data obtained by chemists at Pennsylvania State University. **Page 4**
- Mordecai D. Treblow is elected to the ACS Board of Directors by winning runoff election. **Page 5**
- Chiron's interleukin-2 receives marketing approval from FDA for treatment of kidney cancer, the first interleukin to receive FDA approval. **Page 5**
- Reconvened negotiations on a global chemical weapons treaty face several sticking points, including Russian inability to meet deadlines for destroying chemical arms. **Page 5**
- EPA proposes new Hazardous Waste Identification Rule that would exempt from stringent controls some wastes that pose little or no risk. **Page 6**

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BUSINESS

Charles H. Kline, founder of international business consultants Kline & Co., dies at 73. **Page 21**

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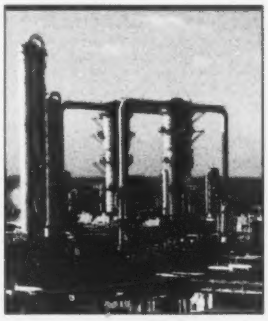

Combined sales of C&EN's Top 100 U.S. chemical producers stumbled in 1991, slipping about 2.5% from 1990 to $181 billion; profitability also fell for most companies. Page 13

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
Robert H. Marks, Director, Publications Division

PUBLISHING BOARD: Ned D. Heindel *(Chairman); Board of Directors Chairman:* Joseph A. Dixon; *President:* Ernest L. Eliel; Richard L. Deming; Judith C. Giordan; William P. Jencks; and Gary J. Long

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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
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LETTERS

CHEMICAL SAFETY

Toxic fluoroethanes

Recent toxicity studies performed by Du Pont have demonstrated that 1,2-difluoroethane (CAS Registry Number 624-72-6) is highly toxic to rodents by the inhalation route. The rat and mouse four-hour approximate lethal concentrations are 75 and 65 ppm, respectively. Clinical and spectroscopic findings suggest that the toxicity of 1,2-difluoroethane may be the result of metabolic conversion to fluorocitrate, an inhibitor of the citric acid cycle. Du Pont has notified the Environmental Protection Agency as well as many manufacturers, marketers, and users of this compound of these findings.

Additional toxicological studies indicate that certain analogs of 1,2-difluoroethane also have highly significant acute toxicity (for example, 1-chloro-2-fluoroethane, 1-bromo-2-fluoroethane, 1-chloro-1,2-difluoroethane). Therefore, in the interest of personal safety, we encourage all researchers to handle these chemicals (as well as all chemicals with unknown toxicological properties) with utmost caution.

If you have any questions regarding the toxicity of these chemicals, please contact the undersigned.

Paul H. Lieder
Senior Research Biochemist
Douglas A. Keller
Research Toxicologist
Du Pont Central Research and Development, Newark, Del.

Bader's unique contributions

A little over a week ago, Al Bader paid me a visit that marked the 10th anniversary of the day he walked into my laboratory while I was a postdoc. I will never forget my initial chagrin at the prospect of listening to yet another salesman. However, my preconceived attitude was completely dispelled after 30 seconds of conversation. In the intervening decade, Bader has never ceased defining to me the true meaning of "commitment to excellence." His voice has always been one of encouragement and optimism.

Unfortunately, we did not have time to reminisce during our last visit. Events at Sigma-Aldrich had drawn a depressing veil over what should have been an invigorating chat. To hear Bader accused of anything less than complete and enthusiastic support for Sigma-Aldrich is completely at odds with the man I have come to know so well. The actions of the board of directors of Sigma-Aldrich reflect a depressing lack of respect for an individual who has made a truly unique contribution to science and scientists.

Sigma-Aldrich and the chemical community have enjoyed a win-win relationship over the years owing to Bader's stewardship. Removal of his emeritus position and board membership now offers the unwelcome prospect of a lose-lose situation for the general chemical community and Sigma-Aldrich. Perhaps a clear sound of protest from chemists may alert sympathetic board members and shareholders to the need to immediately reverse recent, misguided board actions.

John W. Frost
Associate Professor
Purdue University

Chemical weapons

The book review, "Assessing Chemical Weapons' Risk" (C&EN, March 23, page 74), states, "Hitler, who possessed nerve gas weapons, could have used them effectively against the Allies, who didn't have these arms."

As a civilian Army employee from May to September 1945 on a team investigating German industry, I remember that we were told by Col. Haworth, the chemical officer on the staff of the U.S. Second Army, of an incident that occurred as U.S. troops approached the town of Ingolstadt, on the upper Danube. The German commander sent a flag of truce with a message asking that no action be taken within a radius of two miles from the riverfront where two barges were tied up. The barges were loaded with "poison gas" against which the Germans had no protection. The Americans got samples, which could not be identified in Europe, and had to be sent back to the U.S. for identification. The barges were found to be loaded with nerve gases.

The point is that even Hitler would not use the nerve gases against an enemy unless he could protect his own people from them. This apparently did not keep Saddam Hussein from reportedly using nerve gas against rebels.

W. E. Gloor
ACS Member Emeritus
Wilmington, Del.

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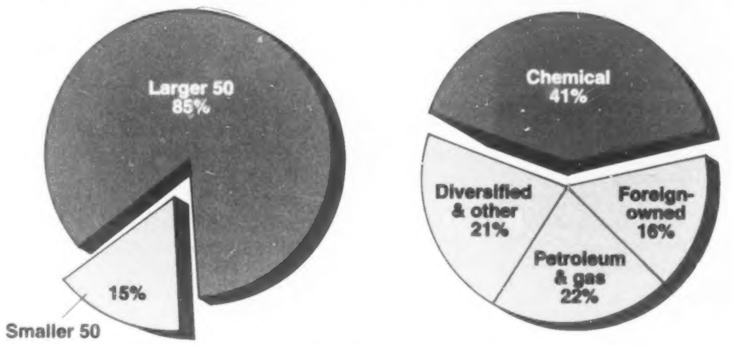
Top 100 Chemical Producers See Sales Slip in 1991

■ ***Chemical profitability for most U.S. companies also declined as global recession slowed demand and softened prices***

William J. Storck,
C&EN Northeast News Bureau

Large firms, mostly chemical, continue to dominate sales



1991 sales = $181 billion

Note: Based on chemical sales figures for Top 100 producers listed on pages 14 and 15.

Last year, U.S. chemical producers overall took a hit on sales, as demand for their products slowed around the world and, consequently, product pricing was soft.

As a group, the companies making up C&EN's annual ranking of the Top 100 chemical producers registered chemical sales down about 2.5% from the year before to about $181 billion. And sales of 1991's list of companies were off about 2.1% from those of the companies listed for 1990 (C&EN, May 6, 1991, page 11).

This is not surprising in a year that began on a weak note with companies confronted by lackluster demand and prices and, at the same time, higher raw material costs brought about by the Persian Gulf War. When the war ended, raw material costs abated, but weak demand and pricing remained. These conditions persisted throughout the year with each quarter's results being below those of the corresponding quarter in the previous year, which had been already depressed by economic downturn.

About the only good news last year was in exports of chemical products, up more than 10% from the previous year (C&EN, April 27, page 21). Some areas of the chemical industry, notably plastic resins, had huge increases in exports. But often these increases came with lower selling prices, so that improvements in dollar sales did not match increases in physical volume.

The decrease in dollar volume was widespread throughout the list of major chemical producers—47 of the 100 companies had declines in sales in 1991 compared with the year before. And a number of other firms reported increases of 1% or less. This number is up significantly from the year before when, despite the recession, 35 of the companies listed showed declines in chemical sales. In addition, of 79 companies reporting operating profits (sales less cost of goods and administrative expenses), 43, or 54%, had lower profits in 1991 than they had had the year before.

Though the list was largely unchanged in terms of financial figures, it was relatively stable in its makeup. Only four companies appear in this ranking that were not on the tabulation for 1990. These include CBI Industries, owner of Liquid Carbonic, the industrial gas supplier, ranked 68th; Rexene, the troubled petrochemical producer, ranked 80th; and Lonza, which had not provided data for the ranking last year, but this year resumed making its sales figure available, ranked 87th. New to the list is Union Carbide Industrial Gases, the soon-to-be-spun-off industrial gases segment of Union Carbide. Although officially still a part of the Danbury, Conn.-based chemical company, it is being regarded by Union Carbide as a discontinued operation, and for 1991 the subsidiary issued its own annual report. Thus, to avoid problems in combining the financial results of the two entities, C&EN chose to treat them as separate firms for 1991, because they probably will be separate by the end of the second quarter of this year. As a result, Union Carbide Industrial Gases was number 20 and Union Carbide slipped to number six from number four last year.

The four companies that dropped off the list are Chemed, which essentially no longer has chemical manufacturing capabilities; Hoffmann-La Roche, which did not provide chemical sales, and Aceto and Eagle-Picher, which were replaced by companies with larger sales.

The fact that Lonza reappears on the Top 100 chemical producers list this year after being off the year before and that Hoffmann-La Roche is not on this year points up the problem of compiling a valid listing. Many foreign-owned and privately held companies simply either do not break out chemical sales or refuse to make them public.

As many name changes are on the list this year as there are new companies. Atochem now appears as Elf Atochem,

Chemical sales declined for almost half of Top 100 chemical producers in 1991

Rank 1991	1990		Chemical sales 1991 ($ millions)	Change from 1990	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1990	Chemical operating profits as % of total profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
1	1	**Du Pont**	$15,383	−1.2%	39.8%	Diversified	$1265	−35.7%	36.2%	8.2%	$13,505	42.4%	9.4%
2	2	**Dow Chemical**	13,277	−9.6	70.6	Basic chemicals	835	−56.6	40.7	6.3	13,460	54.4	6.2
3	3	**Exxon**	10,703	−4.0	9.3	Petroleum	672	−8.8	7.6	6.3	8,630	9.9	7.8
4	6	**Hoechst Celanese**	6,347	15.4	93.4	Basic chemicals	488	14.3	103.2	7.7	na	na	na
5	5	**Monsanto**	5,451	−4.6	61.5	Basic chemicals	694	11.2	68.6	12.7	4,754	51.5	14.6
6	4	**Union Carbide**	4,877	−6.9	100.0	Basic chemicals	122	−80.4	100.0	2.5	4,761	100.0	2.6
7	7	**General Electric**	4,722[d]	−8.6	7.8	Diversified	803	−21.0	10.1	17.0	8,340	5.0	9.6
8	8	**Occidental Petroleum**	4,649	−7.8	40.4	Petroleum	53	−91.7	5.0	1.1	5,150	32.0	1.0
9	9	**BASF**	3,959	−9.3	79.8	Basic chemicals	na	na	na	na	na	na	na
10	11	**Mobil**	3,953	−3.2	6.3	Petroleum	245	−38.3	5.2	6.2	3,294	7.8	7.4
11	10	**Amoco**	3,893	−4.7	13.8	Petroleum	56	−77.8	2.3	1.4	3,858	12.8	1.5
12	13	**Eastman Kodak**	3,740	4.2	19.3	Photo equipment	538	−10.6	22.6	14.4	4,035	16.7	13.3
13	14	**W. R. Grace**	3,531	−1.1	58.4	Specialty chemicals	426	−1.2	118.7	12.1	2,677	44.6	15.9
14	12	**Shell Oil**	3,378	−9.1	15.2	Petroleum	264	−49.1	57.0	7.8	3,989	14.2	6.6
15	15	**Chevron**	3,098	−6.8	7.7	Petroleum	196	345.5	7.3	6.3	2,612	8.0	7.5
16	16	**Arco Chemical**	2,837	0.2	100.0	Basic chemicals	398	−15.1	100.0	14.0	3,676	100.0	10.8
17	17	**Rohm & Haas**	2,763	−2.2	100.0	Basic chemicals	327	−6.8	100.0	11.8	2,495	100.0	13.1
18	19	**Air Products[e]**	2,676	2.4	91.3	Basic chemicals	474	7.7	108.4	17.7	3,445	90.7	13.8
19	20	**Miles**	2,479	11.4	40.0	Diversified chemicals	na	na	na	na	na	na	na
20	—	**Union Carbide Ind. Gases**	2,469	2.0	92.5	Basic chemicals	324	−20.8	100.0	13.1	3,451	100.0	9.4
21	18	**Allied-Signal**	2,459	−11.7	20.8	Diversified	183	−36.2	32.9	7.4	1,949	18.8	9.4
22	22	**American Cyanamid**	2,344	4.0	47.0	Basic chemicals	222	13.8	36.7	9.5	1,788	48.2	12.4
23	21	**Rhône-Poulenc**	2,300	1.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
24	23	**Ashland Oil[e]**	2,285	1.8	23.2	Petroleum	98	40.0	33.3	4.3	834	15.3	11.8
25	24	**Hercules**	2,172	−1.0	74.2	Basic chemicals	201	20.4	101.5	9.3	1,913	72.5	10.5
26	26	**Ciba-Geigy**	2,151	10.0	52.0	Specialty chemicals	na	na	na	na	na	na	na
27	29	**Akzo**	1,913	1.0	100.0	Basic chemicals	na	na	na	na	na	na	na
28	25	**Phillips Petroleum**	1,904	−10.2	15.1	Petroleum	297	−33.7	24.0	15.6	1,970	17.2	15.1
29	27	**Quantum Chemical**	1,885	−3.8	74.4	Basic chemicals	99	−59.3	112.7	5.2	2,219	69.4	4.4
30	33	**Dow Corning**	1,845	7.4	100.0	Specialty chemicals	na	na	na	na	na	na	na
31	31	**Alcoa**	1,842	0	18.6	Nonferrous metals	535	−59.5	114.7	29.0	2,690	24.8	19.9
32	28	**B. F. Goodrich**	1,778	−8.3	71.9	Basic chemicals	35	−73.2	49.8	1.9	1,425	67.4	2.4
33	34	**National Starch**	1,756	5.1	100.0	Specialty chemicals	269	5.9	100.0	15.3	1,635	100.0	16.5
34	35	**FMC**	1,684	3.7	43.2	Machinery	203	6.0	46.4	12.1	1,455	58.9	14.0
35	30	**Lyondell Petrochemical**	1,666	−11.8	32.0	Petroleum products	249	−44.4	47.7	14.9	na	na	na
36	36	**Ethyl**	1,535	−3.5	59.6	Basic chemicals	231	−25.1	59.2	15.0	1,320	16.7	17.5
37	32	**Texaco**	1,515	−12.1	4.1	Petroleum	4	−93.3	0.3	0.3	1,398	6.7	0.3
38	37	**Elf Atochem**	1,500	−2.6	100.0	Basic chemicals	na	na	na	na	na	na	na
39	38	**Degussa**	1,359	−5.2	85.0	Specialty chemicals	na	na	na	na	na	na	na
40	39	**Lubrizol**	1,349	1.0	91.4	Specialty chemicals	179	−55.0	106.9	13.3	862	73.6	20.8
41	48	**Great Lakes Chemical**	1,308	22.6	100.0	Specialty chemicals	350	20.8	100.0	26.8	1,649	100.0	21.2
42	44	**Nalco Chemical**	1,237	2.1	100.0	Specialty chemicals	227	7.6	100.0	18.3	1,324	100.0	17.1
43	50	**Morton International[f]**	1,215	18.9	63.7	Specialty chemicals	153	9.7	71.4	12.6	1,225	68.8	12.5
44	43	**Unocal**	1,213	−1.9	11.1	Petroleum	89	−22.6	42.0	7.3	662	6.7	13.4
45	40	**Huntsman Chemical**	1,200	−7.7	100.0	Basic chemicals	na	na	na	na	na	na	na
46	41	**Tenneco**	1,160	−10.6	8.5	Diversified	66	−60.5	12.0	5.7	1,443	7.9	4.6
47	47	**IMC Fertilizer[f]**	1,131	2.3	100.0	Agrochemicals	196	14.6	100.0	17.3	1,739	100.0	11.3
48	46	**Cabot[e]**	1,129	2.0	76.1	Basic chemicals	103	−29.9	91.6	9.1	1,060	72.5	9.7
49	49	**Imcera Group[f]**	1,127	10.0	69.0	Specialty chemicals	135	29.1	72.9	11.9	1,124	49.9	12.0
50	45	**PPG Industries**	1,100	−4.3	19.4	Glass products	195	−15.6	34.3	17.7	1,076	17.8	18.1

Rank 1991	Rank 1990		Chemical sales 1991 ($ millions)	Change from 1990	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1990	Chemical operating profits as % of total profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
51	54	**Farmland Industries**[g]	$1036	7.3%	28.5%	Agricultural supplies	$123	47.3%	85.3%	11.9%	$442	38.3%	27.9%
52	56	**Inspiration Resources**	1023	6.4	96.4	Agrochemicals	35	46.2	82.4	3.4	352	70.4	10.0
53	55	**International Flavors**	1017	5.6	100.0	Specialty chemicals	254	4.5	100.0	25.0	1217	100.0	20.9
54	52	**Solvay America**	1010	1.3	100.0	Basic chemicals	na	na	na	na	na	na	na
55	51	**Reichhold Chemicals**	1000	0.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
56	42	**Olin**	960	−24.3	42.2	Basic chemicals	na	na	na	na	982	48.8	na
57	60	**Freeport-McMoRan**	880	6.7	55.8	Agrochemicals	71	37.4	31.7	8.1	1143	32.1	6.2
58	64	**H. B. Fuller**[h]	853	7.7	100.0	Specialty chemicals	60	15.3	100.0	7.0	509	100.0	11.8
59	53	**Aristech**	844	−13.3	100.0	Basic chemicals	na	na	na	na	na	na	na
60	58	**NL Industries**	840	−7.3	100.0	Basic chemicals	139	−44.7	100.0	16.5	1831	100.0	7.6
61	57	**Georgia Gulf**	838	−10.1	100.0	Basic chemicals	171	−25.4	100.0	20.3	416	100.0	41.0
62	62	**Uniroyal Chemical**	832	3.0	100.0	Specialty chemicals	102	−5.6	100.0	12.3	1143	100.0	9.0
63	63	**Engelhard**	809	0.3	33.2	Diversified	111	10.8	69.8	13.7	813	64.7	13.6
64	59	**CF Industries**	803	−11.1	100.0	Agrochemicals	78	71.2	100.0	9.7	837	100.0	9.3
65	65	**Witco**[i]	793	3.1	48.6	Specialty chemicals	72	−12.6	52.5	9.0	478	39.9	15.0
66	71	**Pfizer**	730	−18.1	10.5	Drugs	57	−17.4	5.7	7.8	795	8.3	7.2
67	66	**Vista Chemicals**[e]	705	−1.9	100.0	Basic chemicals	na	na	na	na	na	na	na
68	—	**CBI Industries**	698	5.4	43.2	Construction	107	4.3	63.8	15.3	na	na	na
69	61	**Fina**	667	−18.0	20.5	Petroleum	103	−35.4	87.9	15.5	462	16.1	22.4
70	68	**Betz Laboratories**	666	11.5	100.0	Specialty chemicals	119	14.3	100.0	17.9	476	100.0	25.0
71	73	**Sterling Chemical**[e]	643	27.0	118.4	Basic chemicals	61	−30.1	100.0	9.4	361	100.0	16.8
72	70	**Merck**	583	5.8	6.8	Drugs	78	15.5	2.6	13.4	548	8.6	14.3
73	69	**Loctite**	561	1.1	100.0	Specialty chemicals	99	0.5	100.0	17.6	529	100.0	18.7
74	77	**Intl. Specialty Products**	526	2.8	100.0	Specialty chemicals	141	5.6	100.0	26.7	na	na	na
75	78	**Hüls**	500	7.5	100.0	Specialty chemicals	na	na	na	na	na	na	na
76	80	**Sigma-Aldrich**	498	13.2	84.5	Specialty chemicals	119	14.9	96.0	23.9	529	88.7	22.5
77	72	**Ferro**	476	−7.2	45.0	Specialty materials	9	−8.0	12.2	1.9	248	44.9	3.7
78	79	**Union Camp**	471	2.3	15.9	Diversified	27	20.3	9.7	5.7	358	7.6	7.5
79	67	**Kerr-McGee**	454	−29.3	13.9	Petroleum	101	−17.9	37.8	22.2	755	24.2	13.4
80	—	**Rexene**	450	−10.4	100.0	Basic chemicals	12	−85.2	100.0	2.7	441	100.0	2.7
81	81	**Dexter**	429	−2.2	45.7	Specialty chemicals	3	−91.4	8.0	0.8	299	44.2	1.1
82	82	**Borden Chemicals**	420	−0.1	100.0	Basic chemicals	93	8.4	100.0	22.0	507	100.0	18.2
83	76	**Sun Co.**	415	−14.6	3.5	Petroleum	na	na	na	na	na	na	na
84	84	**Stepan**	414	16.3	100.0	Specialty chemicals	21	−9.1	100.0	5.2	233	100.0	9.2
85	83	**Vulcan Materials**	359	−12.2	35.7	Nonmetallic minerals	43	−41.2	50.5	11.9	na	na	na
86	85	**Crompton & Knowles**	341	9.6	75.7	Specialty chemicals	51	19.0	72.0	15.1	252	84.2	20.4
87	—	**Lonza**	330	10.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
88	86	**First Mississippi**[f]	327	10.8	60.9	Agrochemicals	36	58.2	128.1	11.1	173	38.3	21.1
89	90	**Mississippi Chemical**[f]	322	27.4	100.0	Farm cooperative	39	691.9	100.0	12.0	325	100.0	11.9
90	87	**Calgon Carbon**	308	8.2	100.0	Basic chemicals	61	−1.9	100.0	19.9	336	100.0	18.2
91	88	**Petrolite**[j]	305	7.7	94.1	Specialty chemicals	22	32.8	91.1	7.3	196	80.3	11.4
92	75	**Nova**	263	−46.3	100.0	Basic chemicals	na	na	na	na	na	na	na
93	91	**Georgia-Pacific**	223	−9.7	3.7	Wood products	na	na	na	na	na	na	na
94	93	**Sequa Corp.**	213	6.0	11.3	Diversified	37	23.8	31.2	17.2	127	6.0	28.9
95	92	**Quaker Chemical**	191	−5.2	100.0	Specialty chemicals	15	28.6	100.0	8.1	156	100.0	9.9
96	94	**Sherex**	168	−5.4	100.0	Specialty chemicals	na	na	na	na	na	na	na
97	95	**Lawter International**	153	1.9	100.0	Specialty chemicals	30	8.9	100.0	19.7	178	100.0	16.9
98	97	**Cambrex Corp.**	144	8.1	100.0	Specialty chemicals	0[k]	−93.1	100.0	0.2	112	100.0	0.3
99	96	**LeaRonal**[l]	142	1.3	100.0	Specialty chemicals	10	−27.0	100.0	7.2	92	100.0	11.1
100	100	**Sybron**	131	2.7	100.0	Specialty chemicals	na	na	na	na	na	na	na

a Operating profit is sales less administrative expenses and cost of sales. **b** Chemical operating profit as a percentage of sales. **c** Chemical operating profit as a percentage of identifiable chemical assets. **d** Chemical sales include significant amounts of nonchemical products. **e** Fiscal year ended Sept. 30. **f** Fiscal year ended June 30. **g** Fiscal year ended Aug. 31. **h** Fiscal year ended Nov. 30. **i** Does not include all chemical sales. **j** Fiscal year ended Oct. 31. **k** $300,000 does not show because of rounding. **l** Fiscal year ended Feb. 28, 1991. **na** = not available

C&EN's ranking of Top 100 chemical producers by sales, profits, profitability

	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
		Rank			Rank			Rank			Rank			Rank	
$ Millions	1991	1991	1990	1991	1991	1990	1991	1991	1990	1991	1991	1990	1991	1991	1990
Air Products	$ 2,676	18	19	$ 474	9	13	17.7%	13	22	$ 3,445	13	13	13.8%	28	33
Akzo	1,913	27	29	na	—	37	na	—	59	na	—	—	na	—	—
Alcoa	1,842	31	31	535	7	3	29.0	1	1	2,690	15	14	19.9	12	2
Allied-Signal	2,459	21	18	183	29	21	7.4	56	49	1,949	21	20	9.4	49	28
American Cyanamid	2,344	22	22	222	23	30	9.5	45	54	1,788	24	22	12.4	35	52
Amoco	3,893	11	10	56	60	23	1.4	75	67	3,858	10	11	1.5	70	64
Arco Chemical	2,837	16	16	398	11	11	14.0	28	24	3,676	11	10	10.8	43	44
Aristech	844	59	53	na	—	—	na	—	—	na	—	—	na	—	—
Ashland Oil	2,285	24	23	98	48	53	4.3	69	77	834	44	42	11.8	38	62
BASF	3,959	9	9	na	—	—	na	—	—	na	—	—	na	—	—
Betz Laboratories	666	70	68	119	38	45	17.9	12	20	476	55	54	25.0	4	8
Borden Chemicals	420	82	82	93	49	54	22.0	7	25	507	53	46	18.2	14	45
Cabot	1,129	48	46	103	42	39	9.1	48	34	1,060	40	34	9.7	47	36
Calgon Carbon	308	90	87	61	56	56	19.9	9	9	336	63	61	18.2	14	10
Cambrex Corp.	144	98	97	0	79	80	0.2	79	76	112	74	—	0.3	73	—
CBI Industries	698	68	—	107	41	—	15.3	22	—	na	—	—	na	—	—
CF Industries	803	64	59	78	51	60	9.7	44	70	837	43	43	9.3	52	67
Chevron	3,098	15	15	196	27	63	6.3	61	80	2,612	17	16	7.5	57	73
Ciba-Geigy	2,151	25	26	na	—	—	na	—	—	na	—	—	na	—	—
Crompton & Knowles	341	86	85	51	62	64	15.1	24	30	252	66	64	20.4	11	19
Degussa	1,359	39	38	na	—	—	na	—	—	na	—	—	na	—	—
Dexter	429	81	81	3	78	65	0.8	77	54	299	65	62	1.1	71	34
Dow Chemical	13,277	2	2	835	2	2	6.3	61	35	13,460	2	2	6.2	62	31
Dow Corning	1,845	30	33	na	—	—	na	—	—	na	—	—	na	—	—
Du Pont	15,383	1	1	1265	1	1	8.2	50	38	13,505	1	1	9.4	51	30
Eastman Kodak	3,740	12	13	538	6	9	14.4	27	23	4,035	8	8	13.3	32	27
Elf Atochem	1,500	38	37	na	—	—	na	—	—	na	—	—	na	—	—
Engelhard	809	63	63	111	40	48	13.7	29	40	813	45	41	13.6	29	49
Ethyl	1,535	36	36	231	21	19	15.0	25	15	1,320	33	30	17.5	17	9
Exxon	10,703	3	3	672	5	6	6.3	61	64	8,630	3	3	7.8	55	60
Farmland Industries	1,036	51	54	123	36	50	11.9	39	54	442	57	56	27.9	3	16
Ferro	476	77	72	9	76	77	1.9	73	78	248	67	60	3.7	66	71
Fina	667	69	61	103	42	36	15.5	21	13	462	56	47	22.4	6	4
First Mississippi	327	88	86	36	66	69	11.1	43	60	173	71	67	21.1	8	38
FMC	1,684	34	34	203	24	31	12.1	36	45	1,455	28	26	14.0	27	40
Freeport-McMoRan	880	57	60	71	54	58	8.1	51	66	1,143	36	40	6.2	62	68
H. B. Fuller	853	58	64	60	58	58	7.0	60	64	509	52	49	11.8	38	53
General Electric	4,722	7	7	803	3	5	17.0	18	13	8,340	4	4	9.6	48	43
Georgia Gulf	838	61	57	171	31	28	20.3	8	7	416	59	53	41.0	1	1
Georgia-Pacific	223	93	91	na	—	—	na	—	—	na	—	—	na	—	—
B. F. Goodrich	1,778	32	28	35	67	41	1.9	73	63	1,425	30	25	2.4	69	61
W. R. Grace	3,531	13	14	426	10	14	12.1	36	44	2,677	16	15	15.9	22	26
Great Lakes Chemical	1,308	41	48	350	12	34	26.8	2	5	1,649	26	29	21.2	7	15
Hercules	2,172	25	24	201	25	33	9.3	47	62	1,913	22	21	10.5	44	58
Hoechst Celanese	6,347	4	6	488	8	15	7.7	55	60	na	—	—	na	—	—
Hüls	500	75	78	na	—	—	na	—	—	na	—	—	na	—	—
Huntsman Chemical	1,200	45	40	na	—	—	na	—	—	na	—	—	na	—	—
IMC Fertilizer	1,131	47	47	196	26	32	17.3	16	26	1,739	25	24	11.3	41	51
Imcera	1,127	49	49	135	35	45	11.9	39	50	1,124	38	35	12.0	36	56
Inspiration Resources	1,023	52	56	35	67	—	3.4	70	—	352	62	—	10.0	45	—

	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
		Rank			Rank			Rank			Rank			Rank	
$ Millions	1991	1991	1990	1991	1991	1990	1991	1991	1990	1991	1991	1990	1991	1991	1990
International Flavors	$1017	53	55	$254	18	25	25.0%	4	6	$1217	35	33	20.9%	9	11
Intl. Specialty Products	526	74	77	141	33	35	26.7	3	2	na	—	—	na	—	—
Kerr-McGee	454	79	67	101	45	42	22.2	6	16	755	47	45	13.4	30	18
Lawter International	153	97	95	30	69	68	19.7	10	17	178	70	68	16.9	19	20
LeaRonal	142	99	96	10	75	76	7.2	59	51	92	75	72	11.1	42	22
Loctite	561	73	69	99	46	61	17.6	15	57	529	50	50	18.7	13	54
Lonza	330	87	—	na	—	—	na	—	—	na	—	—	na	—	—
Lubrizol	1349	40	39	179	30	16	13.3	31	3	862	42	39	20.8	10	3
Lyondell Petrochemical	1666	35	30	249	19	—	14.9	26	—	na	—	—	na	—	—
Merck	583	72	70	78	51	54	13.4	30	43	548	49	48	14.3	26	37
Miles	2479	19	20	na	—	—	na	—	—	na	—	—	na	—	—
Mississippi Chemical	322	89	90	39	64	79	12.0	38	79	325	64	59	11.9	37	72
Mobil	3953	10	11	245	20	17	6.2	64	52	3294	14	12	7.4	59	46
Monsanto	5451	5	5	694	4	8	12.7	33	46	4754	7	7	14.6	25	41
Morton International	1215	43	50	153	32	40	12.6	34	31	1225	34	—	12.5	34	—
Nalco Chemical	1237	42	44	227	22	29	18.3	11	20	1324	32	37	17.1	18	17
National Starch	1756	33	34	269	16	22	15.3	22	27	1635	27	27	16.5	21	21
NL Industries	840	60	58	139	34	24	16.5	19	4	1831	23	19	7.6	56	42
Nova	263	92	75	na	—	—	na	—	—	na	—	—	na	—	—
Occidental Petroleum	4649	8	8	53	61	7	1.1	76	38	5150	5	6	1.0	72	48
Olin	960	56	42	na	—	—	na	—	—	982	41	38	na	—	—
Petrolite	305	91	88	22	71	74	7.3	57	68	196	69	66	11.4	40	63
Pfizer	730	66	71	57	59	67	7.8	53	72	795	46	55	7.2	60	65
Phillips Petroleum	1904	28	25	297	15	12	15.6	20	10	1970	20	23	15.1	23	7
PPG Industries	1100	50	45	195	27	27	17.7	13	12	1076	39	36	18.1	16	12
Quaker Chemical	191	95	92	15	73	71	8.1	51	47	156	72	69	9.9	46	32
Quantum Chemical	1885	29	27	99	46	26	5.2	67	40	2219	19	18	4.4	65	50
Reichhold Chemicals	1000	55	51	na	—	—	na	—	—	na	—	—	na	—	—
Rexene	450	80	—	12	74	—	2.7	71	—	441	58	—	2.7	67	—
Rhône-Poulenc	2300	23	21	na	—	—	na	—	—	na	—	—	na	—	—
Rohm & Haas	2763	17	17	327	13	18	11.8	42	40	2495	18	17	13.1	33	29
Sequa Corp.	213	94	93	37	65	66	17.2	17	28	127	73	71	28.9	2	5
Shell Oil	3378	14	12	264	17	10	7.8	53	29	3989	9	8	6.6	61	39
Sherex	168	96	94	na	—	—	na	—	—	na	—	—	na	—	—
Sigma-Aldrich	498	76	80	119	38	45	23.9	5	8	529	50	51	22.5	5	13
Solvay America	1010	54	52	na	—	—	na	—	—	na	—	—	na	—	—
Stepan	414	84	84	21	72	73	5.2	67	69	233	68	63	9.2	53	59
Sterling Chemical	643	71	73	61	56	49	9.4	46	19	361	60	57	16.8	20	6
Sun Co.	415	83	76	na	—	—	na	—	—	na	—	—	na	—	—
Sybron	131	100	100	na	—	—	na	—	—	na	—	—	na	—	—
Tenneco	1160	46	41	66	55	33	5.7	65	37	1443	29	28	4.6	64	47
Texaco	1515	37	32	4	77	57	0.3	78	74	1398	31	31	0.3	73	70
Union Camp	471	78	79	27	70	71	5.7	65	73	358	61	57	7.5	57	66
Union Carbide	4877	6	4	122	37	4	2.5	72	32	4761	6	5	2.6	68	35
Union Carbide Ind. Gases	2469	20	—	324	14	—	13.1	32	—	3451	12	—	9.4	49	—
Uniroyal Chemical	832	62	62	102	44	44	12.3	35	33	1143	36	32	9.0	54	57
Unocal	1213	44	43	89	50	43	7.3	57	53	662	48	44	13.4	30	24
Vista Chemicals	705	67	66	na	—	38	na	—	11	na	—	—	na	—	—
Vulcan Materials	359	85	83	43	63	52	11.9	39	18	na	—	—	na	—	—
Witco	793	65	65	72	53	51	9.0	49	47	478	54	52	15.0	24	23

Note: Companies giving only net profits are not ranked. There are 81 firms ranked for operating profits and operating profit margins and 74 ranked for chemical assets and return on assets.
na = not available

reflecting its French parentage. American Petrofina has simplified its name to Fina. GAF's spun-off chemical operations are now called International Specialty Products. And Terra Chemicals is listed more accurately as Inspiration Resources, its corporate parent.

The contributions of companies to total sales in terms of size remained fairly close this year to that of the past few rankings. The 50 largest producers accounted for about $155 billion in chemical sales in 1991 or about 85% of the total. Although this shows considerable growth from five years earlier when the figure was about 80%, it is down slightly from 86% for the 1990 ranking.

Sales broken down by types of producing companies also have remained relatively constant. Chemical companies, or those companies with 50% or more of their sales in chemicals, are by far the biggest sector, accounting for 41% of the total chemical sales on the list. This group is distantly followed by oil and gas companies, whose chemical sales make up 22% of the total. The diversified and other category weighs in with 21% of total sales, and foreign-owned firms make up 16% of the total. Chemical sales for foreign-owned companies are sales from their U.S. subsidiaries only.

Chemical operations at those firms defined as chemical companies are, on average, smaller than for any of the other categories, however. The 14 oil and gas producers on the list averaged chemical sales of $2.84 billion per company; the 19 diversified and other companies averaged chemical sales of $2.02 billion; and the 17 foreign-owned firms averaged chemical sales of $1.68 billion. The 50 firms classified as chemical companies averaged chemical sales of just $1.49 billion per company.

Changes in rankings were relatively few in 1991. In the past, major changes have generally been spurred by acquisitions and divestitures, of which there were few of major importance last year. Once again, as it has been since C&EN began compiling this list, Du Pont was number one. Most other companies in the top 10 simply repeated their positions from the year-earlier ranking—Dow number two, Exxon number three, Monsanto number five, General Electric number seven, and BASF number nine. Hoechst Celanese moved up to number four for 1991 from number six the year before. And Union Carbide fell to num-

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ber six from number four as it split off its gases business. The only other change was Mobil, which moved to number 10 from 11th in 1990's ranking, trading places with Amoco.

In terms of operating profits, Du Pont and Dow are again numbers one and two, respectively; General Electric, three; Monsanto, four; Exxon, five; Eastman Kodak, six; Alcoa, seven; Hoechst Celanese, eight; Air Products, nine; and W. R. Grace, 10.

In operating profit margins, the top five companies are Alcoa, Great Lakes Chemical, International Specialty Products, International Flavors & Fragrances, and Sigma-Aldrich. In terms of chemical assets, the top five are Du Pont, number one, followed by Dow, Exxon, General Electric, and Occidental Petroleum. The top five companies for operating return on assets are, in order, Georgia Gulf, Sequa Corp., Farmland Industries, Betz Laboratories, and Sigma-Aldrich. ☐

Industry consultant Kline dies at 73

Charles H. Kline, 73, founder of international business consultants Kline & Co., died of cancer at his Kinnelon, N.J., home on April 23.

Kline, who received both his bachelor's and doctoral degrees in chemistry from Princeton University, started his Fairfield, N.J.-based chemical market research firm in 1959. Kline served as the company's president until 1986, at which time he became an adviser to its

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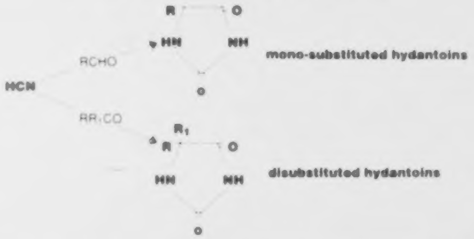

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CHEMICAL & ENGINEERING NEWS

C&EN

MAY 18, 1992

MOST CHEMICAL FIRMS SHOW EARNINGS GAINS, BUT A FEW STILL LAG PAGE 14

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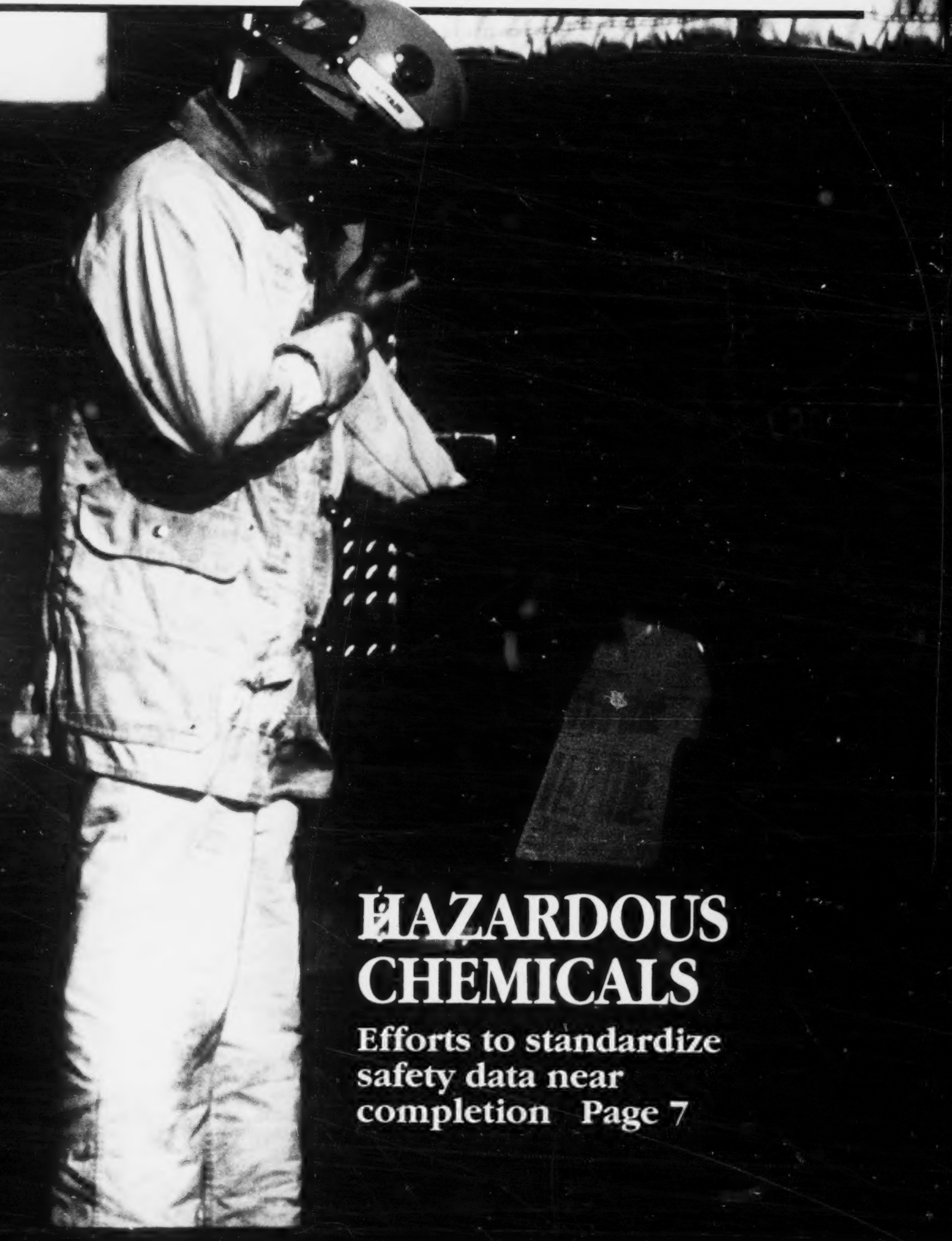

HAZARDOUS CHEMICALS

Efforts to standardize safety data near completion Page 7

CHEMICAL & ENGINEERING NEWS

C&EN

MAY 18, 1992

NEWS OF THE WEEK

- Compromise accord reached by 143 nations on global warming treaty is vague on targets, timetables for reducing carbon dioxide emissions. Page 4
- Two new studies reach vastly different conclusions about the costs of curbing carbon dioxide emissions. Page 4
- In first swaps of emissions allowances for sulfur dioxide, Wisconsin Power & Light announces deal with Pittburgh's Duquesne Light and the Tennessee Valley Authority. Page 5
- Caltech scientists claim isolation of microscopic crystals of the magnetic material magnetite from human brain tissue. Page 6
- Allied-Signal makes biggest investment ever outside U.S. by beginning construction in France of 19,000-metric-ton-per-year plant for making polyester industrial fiber. Page 6

COVER: Fireman consults material safety data sheet during an emergency. Photo courtesy of Chemical Manufacturers Association

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CENEAR 70 (20) 1–56
ISSN 0009-2347

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PARSONS AWARD

Bradford R. Stanerson, retired ACS staff and board member, will receive ACS's 1993 Charles Lathrop Parsons Award. **Page 21**

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First polymer to contain buckminsterfullerene, C_{60}, is synthesized in a simple free-radical process. **Page 26**

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NEWS FOCUS

A standard for material safety data sheets is in the offing, following a four-year effort by industry to better define the format and substance of these forms. Page 7

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1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

Oxygen cylinder accident

We wish to report a bizarre and freak accident. We had used an oxygen cylinder (in a vertical position), reducing its pressure from 3000 psi to about 1500 psi over several weeks. One morning when the main valve of the cylinder (to which a high-pressure regulator was attached) was opened by a counterclockwise turn of 15° to 30°, the valve flew off the cylinder vertically and lodged in a light fixture in the ceiling, allowing the oxygen to escape from the cylinder during a 10-minute period. The threads in the valve indicated that they were stripped, and the Kel-F seat could not be found. The rupture disc on the cylinder was intact. Injury consisted of two badly bruised fingers.

Did the Kel-F ignite? Was the valve thread previously damaged? These questions have yet to be answered. Has this type of accident occurred previously? Our concern is that what happened once may occur again and possibly with other gases.

H. D. Gesser
S. S. Shepelev
Department of Chemistry
University of Manitoba, Winnipeg

Public relations champion

I was saddened to read of the separation of Alfred Bader from Sigma-Aldrich (C&EN, April 6, page 39). In many regards, Bader and Aldrich Chemical are one and the same to many practitioners of organic chemistry.

Thirty some years ago, when I was a fledgling chemist and Aldrich was a fledgling chemical supplier, Bader came to my laboratory to extol the virtues of chemicals supplied by Aldrich. He was also interested in learning how Aldrich could be improved, what they could do for organic chemists, and what reagents they could make that they were not making. In terms of Bader's efforts during the past 30 years, little has changed. He has been a super salesman for Aldrich Chemical and a good friend of organic chemists throughout the world. There is no doubt in my mind that the phenomenal growth of Aldrich was overwhelmingly the result of Bader's efforts. As a consummate organic chemist, Bader was never too busy to talk about organic chemistry. He was always willing to listen to suggestions on ways in which Aldrich might improve its current product line. His visits to my laboratory over the years were always welcomed because I knew that he not only had the best interest of Aldrich at heart, but that he also had the best interest of the bench chemist at heart.

Although I am sure that all of the details and reasons for what would appear to be an unwarranted separation of Bader from Aldrich Chemical will never be available to the casual observer, I am equally sure that Sigma-Aldrich and Bader will both suffer from this dismissal. Public relations is a serious business. Perhaps corporate America should think more carefully before discarding its public relations champions.

Paul G. Gassman
Regents' Professor of Chemistry
University of Minnesota, Minneapolis

Silver-coated beads

There has been a news story in several local papers about Mark Pollock, Solano County (California) District Attorney, and his suit to take the silver-coated beads for cake and cookie decoration off the shelves of bakeries and grocery stores. His basis was the heavy metal toxicity of the silver coating. The three manufacturers of such confections decided not to contest, and withdrew their products. I can understand that, as their sales in a rural county don't profit enough to support the legal fees for at least a millennium.

My instant response was, "How California!"—a comment not pleasing to natives or long-time residents. But then I thought

Correction

- March 9, page 14: The NIH Office of Research on Women's Health workshop will be held June 11–12 at the Bethesda Marriott, not June 12–13 at NIH.

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Signs of Recovery for Chemical Earnings Despite Overall Decrease

■ ***First-quarter results for U.S. chemical companies declined on average, but are distorted by big drop in profits for Dow Chemical***

William J. Storck,
C&EN Northeast News Bureau

The chemical industry finally may be springing to life. Granted, chemical earnings as a whole were down for a group of 30 major U.S. chemical companies in this year's first quarter, but the results were largely skewed by one company—Dow Chemical. Excluding Dow, combined earnings for the group increased more than 10% over the comparable period last year.

And of the 30 companies surveyed by C&EN, only six showed deficits or earnings declines. This is a slight improvement from last year's fourth quarter, when seven of the 30 companies reported declines or deficits. Not only were most chemical companies' earnings up in the first quarter, but a few set earnings records.

For the 30 chemical firms regularly surveyed, first-quarter earnings declined 7% from the year-earlier period to almost $1.20 billion. This represents 11 straight quarters of overall earnings declines for the group. Sales fell 1% in the quarter to almost $20.9 billion. As a result, the aggregate profit margin for the group fell to 5.7% from 6.1% in first-quarter 1991.

However, Dow, with a 53%, or $194 million, decline in earnings, was by far the deciding factor in the overall decline, representing a big chunk of earnings dollars for the other companies to offset. Excluding Dow from the quarterly figures, the remaining 29 companies posted total earnings of $1.03 billion, up 11% from the same quarter last year on relatively unchanged sales of $16.3 billion. And profitability at these 29 companies rose to 6.3% from 5.7%.

If all six of the companies with losses or earnings declines in the first quarter are excluded, combined earnings for the remaining 24 rose 26% to $803 million on a 5% sales gain to $10.7 billion. And the profit margin for the group rose to a very healthy 7.5% from 6.3% in first-quarter 1991.

But even leaving Dow's results in the total provides some hope for recovery during the remainder of this year. The total earnings for the 30 companies in the first quarter were up 46% from the fourth quarter of 1991 on a 2% rise in sales. And the profit margin for the group rose to 5.7% from 4.0% in last year's fourth quarter. Even discounting seasonal variations, a 46% quarter-to-quarter earnings increase is considered good.

For other chemical producers, overall earnings in the first quarter were mixed—down substantially for oil companies but up for both diversified companies and pharmaceutical manufacturers. For 13 oil companies that produce chemicals, for instance, earnings fell a combined 54% to $2.30 billion on a 15% decline in sales to $86.2 billion. Profit margin for the group slipped to 2.7% from 4.9% in last year's first quarter.

For 11 companies that can only be classified as "diversified and other," earnings rose 6% to a combined $1.25 billion as sales fell 1% to about $27 billion. This raised the profit margin for the group to 4.6% in the first quarter from 4.3% a year earlier.

Pharmaceutical companies with their noncyclical products showed the best results. Ten drug companies surveyed posted a combined earnings increase of 14% to $3.19 billion as sales rose 8% to

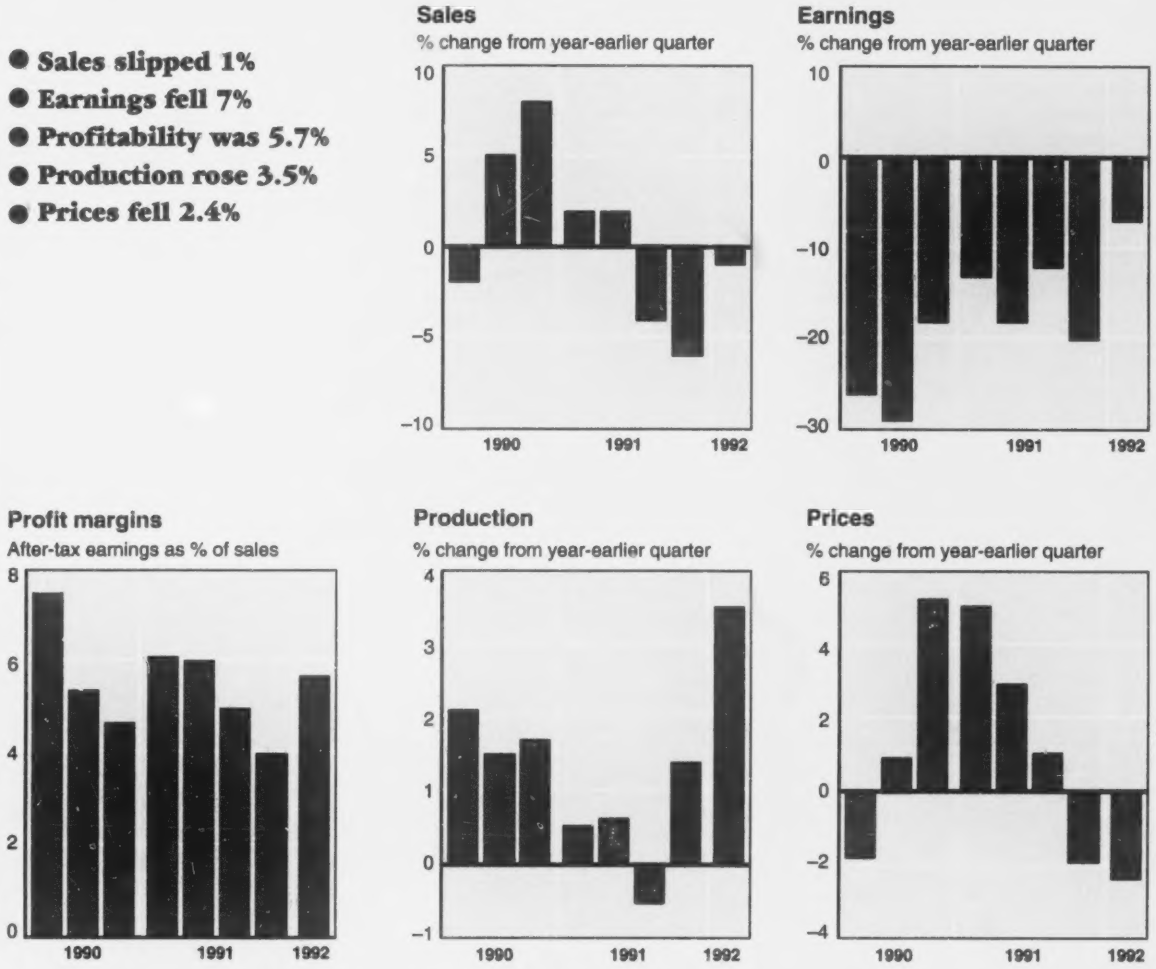
Chemical industry leaders for first-quarter 1992

Sales				Earnings[a]			Profitability		
Rank 1992		$ Millions	Rank 1991		$ Millions	Rank 1991		Earnings as a % of sales	Rank 1991
1	Dow Chemical	$4639.0	1	Dow Chemical	$171.0	1	International Flavors	17.8%	1
2	Monsanto	2188.0	2	Monsanto	161.0	2	Great Lakes Chemical	15.0	2
3	American Cyanamid	1378.6	5	American Cyanamid	114.8	3	Loctite	13.3	4
4	W. R. Grace	1325.9	3	Air Products	73.3	4	Betz Laboratories	11.4	5
5	Union Carbide	1187.0	4	Arco Chemical	61.0	21	Lubrizol	10.6	6
6	Air Products	793.3	7	Rohm & Haas	59.3	8	Nalco Chemical	10.1	2
7	Arco Chemical	762.0	9	Great Lakes Chemical	53.0	10	Air Products	9.2	7
8	Hercules	744.0	6	Ethyl	52.2	6	Crompton & Knowles	8.7	10
9	Rohm & Haas	714.4	10	International Flavors	50.6	7	American Cyanamid	8.3	8
10	Ethyl	681.6	11	Lubrizol	44.1	11	Rohm & Haas	8.3	17

Note: Based on 30 chemical companies listed on page 16. **a** After taxes.

Chemical industry 1992 first-quarter results

- **Sales slipped 1%**
- **Earnings fell 7%**
- **Profitability was 5.7%**
- **Production rose 3.5%**
- **Prices fell 2.4%**



Note: All sales, earnings, and profit-margin data are based on 30 chemical companies listed on page 16.

$17.7 billion. This raised profitability for the group to 18% in the first quarter from 17% in the same period of 1991.

Not only are the financial performances of many chemical producers showing improvement, but also overall chemical economic data are beginning to improve. For instance, the Commerce Department reports that shipments of chemicals and allied products in the first quarter totaled slightly less than $73 billion, up almost 5% from the first quarter of 1991. This increased demand led seasonally adjusted production of chemicals to grow 3.5% in this year's first quarter over the comparable period a year earlier. And chemical capacity utilization has increased slightly to a seasonally adjusted 79.4% in this year's first quarter from 78.8% in the same period last year.

Within the total chemicals segment, however, industrial chemicals are lagging as would be expected since they are the most cyclical part of the industry. For instance, shipments of industrial chemicals in the first quarter totaled about $37.1 billion, down less than 1% from the year-earlier period.

Chemical pricing also remains soft. The average producer price index for chemicals and allied products in the first quarter this year was still down 2.4% from the comparable quarter last year.

In a sense, though, price comparisons for many chemical products as a sign of economic activity during the first quarter are probably not very reliable because of increases in the first quarter last year as a result of instability in the Middle East. Dow was one company hit hard by this factor. The company points out that its sales in first-quarter 1991 were the company's second highest. Frank P. Popoff, Dow's president and chief executive officer, says, "Because of the rapid escalation of prices during the Gulf War, comparisons to that quarter are very difficult." Dow's prices in this year's first quarter were down 11% from a year earlier and robbed the firm of $588 million. Popoff says, however, "The good news is that pricing has become relatively stable over the past six months, feedstock costs have declined,

Earnings improved for most chemical companies in first quarter

	FIRST-QUARTER 1992						12-MONTH RUNNING DATA			
	Sales	Earnings[a]	Change from 1991		Profit margin[b]		Change from 1991		Profit margin[b]	
	($ millions)		Sales	Earnings	1992	1991	Sales	Earnings	1992	1991
Air Products	$ 793.3	$ 73.3	5%	11%	9.2%	8.7%	0%	7%	8.4%	7.8%
American Cyanamid	1,378.6	114.8	5	10	8.3	8.0	11	15	7.0	6.8
Arco Chemical	762.0	61.0	12	259	8.0	2.5	3	−34	5.5	8.6
Betz Laboratories	175.7	20.1	8	10	11.4	11.2	10	13	11.4	11.1
Cabot	417.9	22.0	2	41	5.3	3.8	−11	−19	3.3	3.7
Crompton & Knowles	113.6	9.9	7	21	8.7	7.7	14	20	8.2	7.8
Dow Chemical	4,639.0	171.0	−6	−53	3.7	7.3	−7	−40	4.2	6.5
Ethyl	681.6	52.2	4	5	7.7	7.6	2	−6	8.1	8.8
First Mississippi	122.8	2.3	−6	28	1.9	1.4	3	81	1.8	1.0
H. B. Fuller	218.8	6.0	8	65	2.8	1.8	7	22	3.5	3.0
Georgia Gulf	189.6	13.0	−19	−24	6.8	7.3	−13	−38	7.2	10.2
B. F. Goodrich	605.3	0.1	5	def	0	def	3	−87	0.5	4.0
W. R. Grace	1,325.9	19.0	−10	−41	1.4	2.2	−9	2	3.3	2.9
Great Lakes Chemical	354.6	53.0	7	37	15.0	11.7	19	18	12.8	12.8
Hercules	744.0	36.9	−3	14	5.0	4.2	−9	22	4.9	3.7
IMC Fertilizer	267.5	20.3	−7	9	7.5	6.5	−5	2	8.5	8.0
Imcera Group	433.5	32.6	6	20	7.5	6.7	7	24	6.6	5.7
International Flavors	284.1	50.6	5	8	17.8	17.4	4	6	16.7	16.4
Loctite	147.5	19.7	7	24	13.3	11.4	−6	5	13.3	11.9
Lubrizol	414.9	44.1	11	25	10.6	9.5	3	−4	8.8	9.5
Monsanto	2,188.0	161.0	−2	−3	7.4	7.5	−1	24	7.0	5.6
Morton International	555.0	41.2	7	2	7.4	7.8	7	7	7.2	7.2
Nalco Chemical	326.4	33.0	22	6	10.1	11.7	13	5	10.3	11.0
Olin	614.2	23.6	9	11	3.8	3.8	−8	−3	3.0	2.9
Petrolite	79.9	4.3	3	54	5.4	3.6	7	32	5.0	4.0
Quantum Chemical	631.3	−12.1	−15	def	def	2.6	−11	def	def	1.3
Rohm & Haas	714.4	59.3	5	44	8.3	6.1	0	−7	6.5	6.9
Stepan	107.4	4.1	5	69	3.8	2.4	6	6	3.4	3.4
Union Carbide[c]	1,187.0	44.0	−10	−21	3.7	4.2	−10	−83	0.7	3.7
Witco	420.3	18.9	6	13	4.5	4.2	1	16	4.6	4.0
TOTAL	$20,894.2	$1199.2	−1%	−7%	5.7%	6.1%	2%	−15%	5.5%	6.6%

a After-tax earnings from continuing operations, excluding significant nonrecurring and extraordinary items. **b** After-tax earnings as a percentage of sales. **c** Excludes results from industrial gases, now carried as a discontinued business. **def** = deficit.

and we have probably reached the bottom of the economic cycle in the U.S."

Of course, it was commodities that hurt Dow. Operating income for its plastics unit was down 56% from a year ago as was operating income for chemicals and performance products, where the drop was led by chlorinated solvents and softer demand for caustic soda. Its hydrocarbons and energy business had an operating loss of $30 million, compared with an operating income of $25 million in first-quarter 1991. Operating income for consumer specialties grew 17%.

Soft pricing also hurt chemical operations at oil companies. Chemical net earnings at a group of nine oil companies declined a combined 47%. Commenting on Mobil's chemical earnings, which plummeted 89% to just $10 million, chairman Allen E. Murray says, "Earnings were hurt as both U.S. and foreign petrochemical margins receded from last year's levels when strong consumer demand was experienced." He also says that this year's margins were weakened as new industry capacity came on stream.

Shell Oil, whose chemical earnings dropped 45%, says, "Chemical sales volumes increased, reflecting higher demand across most product lines. This resulted in improved performances in downstream chemical businesses. However, earnings in commodity chemicals declined as a result of depressed selling prices due to industry overcapacity."

Despite the lower chemical earnings for oil companies and the six chemical firms—most of which are tied to commodities—it was a good quarter for many other chemical companies—those with more than 50% of their sales in chemicals. In fact, even with the recession, two of the chemical firms set records—Great Lakes Chemical and Lubrizol. Great Lakes Chemical, whose first-quarter earnings grew 37% to $53 million for an all-time quarterly company record, completed the acquisition of Octel Associates, boosting the firm's earnings. Emerson Kampen, the company's chairman, says, "Clearly, Octel Associates played a significant part in the quarter's success." But he is also quick to credit the company's flame-retardant business and its Bio-Lab unit, a supplier of chemicals for swimming pools and spas. Kampen adds, "We

Earnings rise at diversified and drug companies, but plummet at oil firms

	FIRST-QUARTER 1992					
	Sales	Earnings[a]	Change from 1991		Profit margin[b]	
	($ millions)		Sales	Earnings	1992	1991
OIL AND GAS COMPANIES						
Amoco	$ 6,384.0	$ 234.0	–13%	–52%	3.7%	6.7%
Ashland	2,242.3	–9.1	5	def	def	1.2
Chevron	9,700.0	217.0	–10	–63	2.2	5.4
Exxon	27,914.0	1350.0	–9	–40	4.8	7.3
American Petrofina	661.0	–5.5	–19	def	def	1.0
Kerr-McGee	782.7	8.6	0	–71	1.1	3.8
Mobil	15,151.0	213.0	–9	–70	1.4	4.3
Occidental Petroleum	2,154.0	21.0	–22	–76	1.0	3.2
Phillips Petroleum	2,759.0	–26.0	–68	def	def	1.7
Shell Oil	4,990.0	91.0	–12	–27	1.8	2.2
Sun Co.	2,530.0	–13.0	–15	def	def	1.7
Texaco	8,560.0	200.0	–16	–52	2.3	4.1
Unocal	2,421.0	23.0	–11	–62	1.0	2.2
TOTAL	**$86,249.0**	**$2304.0**	**–15%**	**–54%**	**2.7%**	**4.9%**
DIVERSIFIED MANUFACTURERS						
Allied-Signal	$ 2,979.0	$ 127.0	3%	102%	4.3%	2.2%
Du Pont	9,185.0	482.0	–5	–18	5.2	6.1
Eastman Kodak	4,410.0	145.0	0	–19	3.3	4.0
Engelhard	630.0	23.8	0	13	3.8	3.4
FMC	933.9	54.7	6	41	5.9	4.4
Ferro Corp.	272.6	12.9	4	350	4.7	1.1
3M	3,406.0	288.0	1	–4	8.5	8.9
NL Industries	226.1	–4.4	0	def	def	def
PPG Industries	1,446.7	78.8	5	260	5.4	1.6
Tenneco[c]	3,272.0	33.0	–2	3200	1.0	0
Vulcan Materials	210.6	4.6	7	def	2.2	def
TOTAL	**$26,972.0**	**$1245.5**	**–1%**	**6%**	**4.6%**	**4.3%**
PHARMACEUTICAL COMPANIES						
Abbott Laboratories	$ 1,877.9	$ 294.2	14%	16%	15.7%	15.4%
American Home Products	1,998.5	406.3	13	15	20.3	20.0
Baxter International	2,296.0	131.0	8	19	5.7	5.2
Bristol-Myers Squibb	2,783.4	547.5	2	11	19.7	18.0
Eli Lilly	1,557.1	442.6	8	14	28.4	27.1
Merck	2,223.4	568.7	9	18	25.6	23.6
Pfizer	1,761.3	295.1	4	10	16.8	15.8
Schering-Plough	1,021.9	192.9	8	11	18.9	18.2
Upjohn	871.9	143.7	9	8	16.5	16.7
Warner Lambert	1,311.5	163.6	8	17	12.5	11.5
TOTAL	**$17,702.9**	**$3185.7**	**8%**	**14%**	**18.0%**	**17.0%**

a After-tax earnings from continuing operations, excluding significant nonrecurring and extraordinary items. **b** After-tax earnings as a percentage of sales. **c** Includes special item. **def** = deficit.

have started the year at a record-setting pace, with quarterly results well ahead of any mark in company history. This accomplishment affirms Great Lakes' fundamental growth strategies. What's more, I'm convinced that as the year unfolds, we have the means to accelerate our progress on many fronts, including new fuel additives, high-value-added specialty chemicals, select acquisitions, and strategic alliances."

Lubrizol's first-quarter earnings jumped 25% to $44.1 million, setting a company record for any year's first quarter. Company chairman L. E. Coleman says: "We are very pleased with the strength in our specialty chemicals business, which improved during the second half of 1991 and is growing as planned. Additive shipments increased 25% when compared to the weak first quarter of 1991 and are continuing at the same high levels achieved during the third and fourth quarter last year. … We expect to maintain these shipment levels throughout 1992 and expect to match or exceed our historic unit volume growth rate."

For the remainder of the year, chemical executives appear cautiously optimistic as the economy embarks on what seems to be a slow expansion, but they are certainly not ready to commit to ebullience. At Rohm & Haas, chairman and chief executive officer J. Lawrence Wilson says, "The economic climate has improved since the first of the year. If this improvement continues, Rohm & Haas stands ready to take advantage of the higher level of business."

Dow's Popoff says: "Although there are some encouraging signs of recovery from the recession in the U.S., the European economies have weakened and Pacific markets, particularly Japan, have moderated their growth. While the chemical industry tends to lag any upward economic movement by as much as six months, we continue to be optimistic about having positive earnings momentum during the second half of 1992."

At B. F. Goodrich, which showed a small profit in the first quarter after a loss in the same period last year, chairman John D. Ong says, "Demand for many of our specialty chemical products is improving and our aerospace business again reports strong results. If economic conditions continue to strengthen, we would expect to see significant growth in earnings in the quarters ahead."

Probably the most cautious forecast by any chemical company executive was made by Alan R. Hirsig, president and chief executive officer of Arco Chemical. Although the company showed the highest year-to-year growth in earnings of any company on the list at 259%, Hirsig says, "we have not as yet seen the volume growth necessary to indicate a sustained recovery is under way." Hirsig places more credit for the company's good results on lower feedstock costs and the company's cost reduction program that was implemented in the second half of 1991 than he does on economic expansion. ☐

ACS Committee on Professional Training 1991 Annual Report

The number of bachelor's degree graduates in chemistry from colleges and universities whose undergraduate chemistry programs are approved by the American Chemical Society increased 2.9% in the 1990–91 academic year. This reverses the downward trend for the first time since 1983. The number of master's degrees from these departments dropped less than one half a percentage point. This is the second drop in a row. The number of Ph.D. degrees continued to increase for the 13th year in a row. However, the increase of 3.8% was less than half of last year's gain.

The percentage of baccalaureate graduates certified to ACS was 42%. This number has remained fairly constant over the years. (Certified graduates are those who have completed a curriculum that meets the guidelines specified by ACS and who are eligible for full membership in ACS; noncertified graduates may become associate members of ACS upon graduation and full members after three years of professional experience or a higher degree in a chemical science.)

Total numbers of bachelor's degrees (certified and noncertified), master's degrees, and Ph.D. degrees awarded in 1990–91 by departments whose undergraduate chemistry programs are ACS approved are listed by institution in the large table at the end of this report and are summarized in the two smaller tables. These tables also include numbers of chemical engineering graduates from institutions whose programs are accredited by the American Institute of Chemical Engineers and the Accreditation Board for Engineering & Technology. (Note: These departments are not required to report their data to CPT, so the number of departments included varies each year.) Included for the fifth year is a table with information on graduate student enrollments in chemistry departments whose undergraduate programs are ACS approved.

Summary of data from departments offering an ACS-approved program, 1987-91

	Bachelors				Masters		Doctorates	
	Number of schools	Graduates (totals)	Certified graduates[a]	Noncertified graduates	Number of schools	Graduates	Number of schools	Graduates
CHEMISTRY								
1987	582	8848	3663	5185	316	1636	188	1936
1988	584	8372	3453	4919	319	1584	192	1955
1989	593	8125	3384	4741	318	1710	189	1970
1990	599	7650	3213	4437	317	1605	187	2131
1991	599	7872	3310	4562	316	1600	189	2213
CHEMICAL ENGINEERING[b]								
1987	107	4435	4435	—	103	1078	90	533
1988	128	3524	3524	—	124	1036	106	603
1989	115	2891	2981	—	113	919	95	574
1990	126	3170	3170	—	122	956	106	583
1991	120	3081	3081	—	115	816	104	602

[a] Includes graduates certified in approved options. [b] Chemical engineering departments are not required to report their data to CPT, so the number of departments included in this category varies from year to year.

The number of bachelor's degrees in chemical engineering from the 120 AIChE-ABET-accredited departments that reported in 1991 decreased 2.8% after the 9.6% increase reported by 126 departments in 1990. At the graduate level, the number of chemical engineering master's degrees decreased by 15% after an increase of 4% last year. Ph.D. degrees showed a slight increase of 3% for the second year in a row.

The chemistry programs at ACS-approved schools normally are reevaluated at five-year intervals. There were 599 colleges and universities on the approved list at the end of 1991. During the year the committee studied the reports of 290 chemistry programs at approved schools and 15 reports from schools applying for ACS approval. Each evaluation included a review of extensive documentary materials submitted by the department chairman describing the current status of the program.

Three schools were added to the ACS-approved list by CPT; two were put on probation; three were removed from probation; and three were removed from the list. Visiting associates of the committee made on-site visits to 11 schools.

Currently, students may receive certified degrees in chemistry with options in biochemistry, polymers, chemistry education, chemical physics, or materials. By the end of 1991, the com-

Summary of totals from 1991 reports from departments offering ACS-approved program

	Schools reporting	Men	Women	Total
CHEMISTRY				
Bachelors, Total	599	4740	3132	7872
Certified	—	2050	1260	3310
Noncertified	—	2690	1872	4562
Masters	316	952	648	1600
Doctorates	189	1669	544	2213
CHEMICAL ENGINEERING				
Bachelors,				
Certified	120	2108	973	3081
Masters	115	656	160	816
Doctorates	104	524	78	602

mittee had approved 39 programs with a biochemistry option; five with a polymers option; and one chemistry education option.

After consultation with many constituencies, the committee produced a revised set of appendixes to the "ACS Guidelines & Evaluation Procedures for Undergraduate Professional Education in Chemistry." This appendix material contains course suggestions for analytical, biochemistry, chemical information, materials, polymers, inorganic, organic, and physical chemistry courses as well as guidelines for preparing a research report. Copies of the appendixes are available from the Office of Professional Training, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036.

The committee initiated a revision of the ACS guidelines to incorporate requirements for certification of students with a degree in chemistry with an emphasis in biochemistry, polymers, chemistry education, materials, or chemical physics. Also, the committee reviewed information on the library requirements for an ACS-approved program. In order to have the guidelines reflect the best approach in this area, the committee requested input from representatives of the ACS Chemical Information Division and surveyed selected ACS-approved schools regarding library journal holdings and accessibility of electronic information. Based on information gathered, the committee has determined that when a school is unable to maintain a subscription to the print edition of *Chemical Abstracts*, but maintains on-line access, it is very important that there be an adequate budget allowance for on-line searching and that some printed copies of the abstracts and indexes be available to students so they can learn the structure and content of the abstracts and indexes to be able to formulate on-line search requests. Other changes in the library requirements of the guidelines will be included in the 1992 report.

In October 1991, CPT published the 19th edition of the "ACS Directory of Graduate Research." This edition provides information on graduate programs in chemistry, chemical engineering, biochemistry, medicinal-pharmaceutical chemistry, clinical chemistry, and polymer science in 699 academic departments. The committee also formulated a policy by which new sections may be added to future editions of the directory. Possible new sections for the 1993 edition include: toxicology, food science, environmental science, and forensic science.

Other activities of the committee included revising the CPT annual report forms to include data on student ethnicity; publishing the proceedings of the symposium on Innovative Approaches to Teaching Introductory Chemistry; and meeting with the visiting associates of the committee to update them on the core curriculum and optional degrees. The committee also was represented on the ACS Task Force on the Professional Status of Chemical Education; members participated in a Sigma Xi symposium on entry-level undergraduate courses in science; and presented papers at the Joint CPT-SOCED Chemistry Education Symposium.

The committee would like to acknowledge and thank the following visiting associates of the committee who conducted on-site visits to schools on the approved list or applying for ACS approval during 1991: C. A. Arrington Jr., Furman University; Charles P. Casey, University of Wisconsin, Madison; Marcetta Darensbourg, Texas A&M University; Natalie Foster, Lehigh University; John B. Grutzner, Purdue University; William Jones, University of Florida; Heinz F. Koch, Ithaca College; J. C. Martin, Vanderbilt University; Robert F. Pasternak, Swarthmore University; Hans Veening, Bucknell University; Thomas Wartik, Pennsylvania State University. ☐

Graduate student enrollments in departments whose undergraduate chemistry programs are ACS approved

	Number of departments	First-year graduate students		All graduate students	
		Full-time	Part-time	Full-time	Part-time
M.S. DEPARTMENTS[a]					
Fall 1986	128	474	264	1,190	1051
Fall 1987	127	406	315	1,136	993
Fall 1988	127	420	218	998	855
Fall 1989	130	429	238	1,013	834
Fall 1990	125	511	268	1,244	887
Ph.D. DEPARTMENTS					
Fall 1986	187	3475	235	14,438	1355
Fall 1987	192	3441	201	15,212	1231
Fall 1988	189	3320	171	15,125	1111
Fall 1989	187	3464	159	15,222	1207
Fall 1990	189	3535	256	15,470	1148

[a] Departments whose highest offering is the master's degree in chemistry.

Committee members, 1991

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committee chairman
University of California,
San Diego
Hector D. Abruna
Cornell University
Sally Chapman
Barnard College
Norman C. Craig
Oberlin College
Dennis H. Evans
University of Delaware
Gordon A. Hamilton
Pennsylvania State University
Gordon G. Hammes
Duke University
Medical Center
Herbert D. Kaesz
University of California,
Los Angeles
Karen W. Morse
Utah State University
Shalaby W. Shalaby
Clemson University
Walter S. Trahanovsky
Iowa State University
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Barbara A. Gallagher,
committee secretary
Cathy A. Nelson, *staff associate*
Dolphine S. Hite, *program assistant*
American Chemical Society

Chemistry and chemical engineering degrees awarded by schools offering an ACS-approved program, 1990-91

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelors certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Abilene Christian U	6	5	0	—			
Adelphi U	0	2	7	—			
Agnes Scott C	2	1	—	—			
Akron, U of	22	5	2	14	a		
Alabama, U of							
Birmingham	2	0	2	0			
Huntsville	5	5	7	—	a		
Tuscaloosa	6	10	2	7	16	3	0
Alaska Fairbanks, U of	2	6	3	—			
Albion C	4	9	—	—			
Albright C	0	8	—	—			
Alfred U	2	0	—	—			
Allegheny C	0	15	—	—			
Alma C	6	3	—	—			
American U	3	0	2	3			
Amherst C	2	7	—	—			
Andrews U	4	0	—	—			
Appalachian State U	5	7	3	—			
Arizona State U	9	14	2	17	a		
Arizona, U of	17	8	10	28	11	2	4
Arkansas State U	1	4	—	—			
Arkansas Tech U	4	1	—	—			
Arkansas, U of							
Fayetteville	8	4	0	6	36	9	0
Little Rock	2	4	2	—			
Ashland U	0	2	—	—			
Auburn U	7	7	5	6	32	12	5
Augsburg C	4	6	—	—			
Augustana C							
Illinois	0	8	—	—			
South Dakota	2	8	—	—			
Austin C	0	8	—	—			
Austin Peay State U	0	9	—	—			
Baldwin-Wallace C	1	10	—	—			
Ball State U	9	7	3	—			
Barnard C	0	11	—	—			
Bates C	5	2	—	—			
Baylor U	3	17	3	5			
Beloit C	4	11	—	—			
Bemidji State U	5	3	—	—			
Birmingham-Southern C	0	7	—	—			
Bloomsburg U	4	4	—	—			
Boston C	3	2	4	8			
Boston U	8	9	4	8			
Bowdoin C	1	18	—	—			
Bowling Green State U	5	7	4	0			
Bradley U	1	16	0	—			
Brandeis U	0	7	6	7			
Bridgeport, U of	3	0	3	—			
Bridgewater State C	1	4	0	—			
Brigham Young U	15	12	5	11	25	7	4
Brown U	0	3	6	14	4	2	2
Bryn Mawr C	14	0	3	1			
Bucknell U	13	12	3	—	15	2	—
Butler U	2	9	2	—			
California Institute of Tech	4	2	2	21	10	13	11
California Polytechnic State U	10	27	3	—			
California State Poly U	4	3	7	—	a		
California State U							
Bakersfield	1	6	—	—			
Chico	0	13	—	—			
Dominguez Hills	3	1	—	—			
Fresno	8	13	6	—			
Fullerton	5	28	4	—			
Hayward	5	10	5	—			
Long Beach	9	25	13	—	a		
Los Angeles	6	5	2	—			
Northridge	8	14	7	—			
Sacramento	9	5	6	—			
San Bernardino	2	5	—	—			
Stanislaus	0	1	—	—			
California, U of							
Berkeley	28	26	10	55	48	7	19
Davis	33	9	3	31	34	10	3
Irvine	7	30	17	12			
Los Angeles	8	95	15	37	31	9	4
Riverside	13	0	11	10			
San Diego	56	0	15	26	15	1	1
Santa Barbara	0	21	4	18	18	9	5
Santa Cruz	5	15	6	11			
Calvin C	3	1	—	—			
Canisius C	7	5	—	—			
Capital U	2	1	—	—			
Carleton C	6	24	—	—			
Carnegie Mellon U	11	1	6	8	40	7	10
Carroll C	4	2	—	—			
Carthage C	3	4	—	—			
Case Western Reserve U	6	23	6	14	20	10	5
Catholic U of America	3	1	5	6			
Centenary C of Louisiana	0	1	—	—			
Central Connecticut State U	3	1	0				
Central Florida, U of	12	0	5	—			
Central Michigan U	6	15	8	—			
Central Oklahoma, U of	4	7	—	—			
Central State U	1	1	—	—			
Central U of Iowa	0	7	—	—			
Centre C	2	6	—	—			
Charleston, C of	4	13	—	—			
Chatham C	0	0	—	—			
Chestnut Hill C	0	2	—	—			
Chicago State U	0	9	—	—			
Chicago, U of	12	18	13	23			
Christian Brothers C[b]					a		
Cincinnati, U of	21	0	19	29	48	9	8
Citadel, The	1	3	—	—			
City U of New York							
Graduate Center	—	—	—	42			
Brooklyn C	1	15	9	—			
City C	2	3	19	—	a		
Herbert H. Lehman C	7	2	—	—			
Hunter C	0	8	—	—			
Queens C	0	0	9	—			
Clarion U	0	4	—	—			
Clark U	7	2	6	6			
Clarkson U	11	2	13	8	41	11	7
Clemson U	3	14	5	11	29	9	2
Cleveland State U	11	0	7	6	12	1	2
Coe C	1	2	—	—			
Colby C	1	8	—	—			
Colgate U	7	2	—	—			
Colorado C	6	4	—	—			
Colorado School of Mines	10	0	4	6	37	6	3
Colorado State U	7	11	2	23	22	8	1
Colorado, U of							
Boulder	5	43	7	19	27	5	8
Colorado Springs	2	8	—	—			
Denver	7	3	2	—			
Columbia U	4	12	16	20	21	9	2
Concordia C	2	5	—	—			
Connecticut C	3	1	—	—			
Connecticut, U of	13	8	10	12	14	7	4
Cooper Union[b]					a		
Cornell C	0	3	—	—			
Cornell U	18	27	33	19	21	3	4
Creighton U	9	9	—	—			
Dartmouth C	0	14	1	7			
David Lipscomb U	0	20	—	—			
Davidson C	4	2	—	—			
Dayton, U of	6	10	—	—	27	3	—
De Paul U	9	0	8	—			
DePauw U	0	9	—	—			
Delaware State C	1	5	4	—			
Delaware Valley C of Science & Agriculture	4	0	—	—			
Delaware, U of	26	15	3	10	26	4	13
Delta State U	2	7	—	—			
Denison U	0	3	—	—			
Denver, U of	2	5	2	1			
Detroit Mercy, U of	4	6	11	1	a		
District of Columbia, U of the	3	2	—	—			
Dickinson C	0	9	—	—			
Drake U	4	2	—	—			
Drew U	3	3	—	—			
Drexel U	7	0	7	4	41	4	2
Duke U	14	20	2	10			
Duquesne U	0	8	4	1			
Earlham C	1	7	—	—			
East Carolina U	9	8	3	—			
East Stroudsburg U	4	9	1	—			
East Tennessee State U	4	3	2	—			

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelors certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
East Texas State U	1	5	2	—			
Eastern Illinois U	3	3	1	—			
Eastern Kentucky U	3	9	2	—			
Eastern Michigan U	6	16	8	—			
Eastern New Mexico U	1	3	2	—			
Eckerd C	4	0	—	—			
Elizabethtown C	0	7	—	—			
Elmhurst C	0	8	—	—			
Emory U	2	20	5	14			
Emporia State U	3	7	1	—			
Evansville, U of	1	3	—	—			
Fairfield U	5	0	—	—			
Fairleigh Dickinson U							
Madison	4	0	1	—			
Teaneck	5	2	2	—			
Fisk U	5	4	2	—			
Florida A&M U	1	3	—	—	11	1	2
Florida Atlantic U	6	26	4	—			
Florida Institute of Tech	0	4	0	0	a		
Florida International U	8	22	4	—			
Florida State U	0	22	8	8			
Florida, U of	3	33	4	31	19	2	9
Fordham U	0	9	1	—			
Fort Lewis C	4	11	—	—			
Framingham State C	3	0	—	—			
Franklin & Marshall C	13	2	—	—			
Furman U	17	1	4	—			
Geneva C	1	7	—	—			
George Mason U	12	0	4	—			
George Washington U	6	6	1	0			
Georgetown U	15	0	16	4			
Georgia Institute of Tech	29	0	7	8	59	8	7
Georgia Southern C	2	2	—	—			
Georgia State U	5	4	2	—			
Georgia, U of	1	7	6	11			
Gettysburg C	9	1	—	—			
Glassboro State C	6	1	—	—			
Gonzaga U	5	0	—	—			
Goucher C	0	5	—	—			
Grand Valley State U	0	4	—	—			
Grinnell C	2	9	—	—			
Gustavus Adolphus C	3	11	—	—			
Hamilton C	2	2	—	—			
Hamline U	6	9	—	—			
Hampden-Sydney C	6	3	—	—			
Hampton U	8	0	5	—			
Hartford, U of	0	1	0	—			
Hartwick C	1	2	—	—			
Harvard U	26	0	16	25			
Harvey Mudd C	14	0	—	—			
Haverford C	14	2	—	—			
Hawaii, U of	18	2	3	3			
Hendrix C	9	3	—	—			
Hiram C	5	6	—	—			
Hobart & William Smith C	2	6	—	—			
Hofstra U	4	2	—	—			
Hollins C	0	3	—	—			
Holy Cross, C of the	8	3	—	—			
Hope C	12	10	—	—			
Houston, U of	7	2	8	8	22	10	7
Howard U	4	23	1	5	28	0	—
Humboldt State U	1	4	—	—			
Idaho State U	2	4	0	—			
Idaho, U of	3	8	7	4	20	5	4
Illinois Benedictine C	10	2	—	—			
Illinois Institute of Tech	4	0	3	1	25	11	6
Illinois State U	33	3	5	—			
Illinois Wesleyan U	4	2	—	—			
Illinois, U of							
Chicago	17	34	16	15	20	11	3
Urbana-Champaign	62	76	11	51	72	10	13
Indiana State U	7	1	1	—			
Indiana U							
Bloomington	23	94	5	26			
Northwest	3	3	—	—			
South Bend	5	0	—	—			
Pennsylvania	10	4	6	—			
Indiana U-Purdue U							
Fort Wayne	2	4	—	—			
Indianapolis	1	21	7	—			
Interamerican U of Puerto Rico	3	12	—	—			
Iowa State U	9	2	7	53	39	6	2
Iowa, U of	18	0	10	18	a		
Ithaca C	5	0	—	—			

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelors certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Jackson State U	4	3	1	—			
James Madison U	2	16	—	—			
John Carroll C	5	24	4	—			
Johns Hopkins U	17	0	12	9	9	2	6
Juniata C	3	5	—	—			
Kalamazoo C	4	4	—	—			
Kansas State U	3	4	2	7	10	3	1
Kansas, U of	7	17	1	4	18	6	3
Kean C of New Jersey	4	11	—	—			
Kennesaw State C	2	4	—	—			
Kent State U	10	3	1	1			
Kentucky, U of	4	12	6	6	20	8	0
Kenyon C	2	5	—	—			
King's C	7	1	—	—			
Knox C	0	14	—	—			
La Salle U	5	2	—	—			
Lafayette C	7	7	—	—	18	—	—
Lake Forest C	2	4	—	—			
Lamar U	4	1	10	—	11	8	0
Lawrence Technological U	6	0	—	—			
Lawrence U	7	6	—	—			
Le Moyne C	3	2	—	—			
Lebanon Valley C	2	1	—	—			
Lehigh U	4	4	6	11	27	11	13
Lewis & Clark C	2	5	—	—			
Lincoln U	1	13	—	—			
Long Island U							
Brooklyn C	3	0	1	—			
C. W. Post C	2	4	—	—			
Loras C	0	1	—	—			
Louisiana State U							
Baton Rouge	5	3	1	19	25	7	6
Shreveport	2	0	—	—			
Louisiana Technological U	3	3	1	—	a		
Louisville, U of	15	0	0	2	—	18	1
Lowell, U of	5	5	8	13	a		
Loyola C in Maryland	0	3	—	—			
Loyola Marymount U	7	0	—	—			
Loyola U							
Chicago	10	4	0	4			
New Orleans	0	6	—	—			
Luther C	1	2	—	—			
Lycoming C	0	3	—	—			
Macalester C	4	10	—	—			
Maine, U of	4	2	1	3	25	1	2
Manhattan C[c]	6	4	—	—	18	8	—
Manhattanville C	0	0	—	—			
Mankato State U	4	10	4	—			
Marietta C	5	2	—	—			
Marist C	1	0	—	—			
Marquette U	6	0	5	7			
Marshall U	1	13	6	—			
Maryland U of							
Baltimore County	2	27	1	1	9	2	0
College Park	5	51	11	28	17	3	3
Massachusetts Institute of Tech	23	0	3	39	40	39	32
Massachusetts, U of							
Amherst	7	8	11	15	33	3	12
Dartmouth	2	7	5	—			
McNeese State U	5	0	4	—			
Memphis State U	1	9	0	1			
Mercer U	1	6	—	—			
Merrimack C	3	4	—	—			
Metropolitan State C	2	17	—	—			
Miami U	20	21	3	10			
Miami, U of	5	13	2	4			
Michigan State U	16	22	6	22	a		
Michigan Technological U	12	0	6	5	45	9	0
Michigan, U of							
Ann Arbor	55	0	32	29	59	9	8
Dearborn	13	12	—	—			
Flint	1	5	—	—			
Middle Tennessee State U	2	10	6	—			
Middlebury C	4	7	—	—			
Midwestern State U	4	5	—	—			
Millersville U	3	5	—	—			
Millsaps C	2	5	—	—			
Minnesota, U of							
Duluth	7	7	5	—			
Minneapolis	43	0	11	28	98	9	28
Mississippi C	2	4	—	—			
Mississippi State U	3	5	1	1	a		
Mississippi, U of	0	7	7	7	2	3	1

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelors certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Missouri, U of							
Columbia	11	1	10	6	21	4	2
Kansas City	4	21	5	2			
Rolla	5	0	3	7	29	8	3
St. Louis	11	5	1	4			
Missouri Western State C	4	4	—	—			
Monmouth C	2	0	—	—			
Montana C of Mineral Science & Technology	0	1	1	—			
Montana State U	1	3	3	7	21	3	1
Montana, U of	1	7	3	1			
Montclair State C	5	3	2	—			
Moorhead State U	8	4	—	—			
Moravian C	4	0	—	—			
Morehouse C	6	0	—	—			
Morgan State U	6	4	—	—			
Mount Holyoke C	6	8	2	—			
Mount Saint Vincent, C of[c]	1	0	—	—			
Muhlenberg C	2	8	—	—			
Murray State U	4	14	4	—			
Muskingum C	0	2	—	—			
Nazareth C	2	3					
Nebraska Wesleyan U	2	1	—	—			
Nebraska, U of							
Kearney	0	9	—	—			
Lincoln	5	4	9	6	13	5	1
Omaha	1	2	—	—			
Nevada, U of							
Las Vegas	4	6	1	—			
Reno	4	4	2	4	a		
New Hampshire, U of	5	1	5	1	15	1	1
New Jersey Institute of Tech[b]					15	19	6
New Mexico Highlands U	0	1	0	—			
New Mexico Inst. of Mining & Tech	9	0	1	2			
New Mexico State U	1	21	10	8	20	2	1
New Mexico, U of	9	9	4	9	7	8	0
New Orleans, U of	0	3	3	7			
New York U	2	38	25	12			
Niagara U	0	8	—	—			
North Alabama, U of	5	21	—	—			
North Carolina A&T State U	6	0	0	—			
North Carolina Central U	1	4	1	—			
North Carolina State U	32	41	5	10	77	4	7
North Carolina, U of							
Asheville	1	4	—	—			
Chapel Hill[e]	27	44	12	39			
Charlotte	4	10	2	—			
Greensboro	7	6	4	—			
Wilmington	5	9	—	—			
North Dakota State U	0	13	2	5			
North Dakota, U of	2	10	1	1	13	3	—
North Texas, U of	3	7	9	6			
Northeast Louisiana U	0	2	5	—			
Northeast Missouri State U	9	0	—	—			
Northeastern Illinois U	0	19	3	—			
Northeastern U	3	0	6	7	a		
Northern Arizona U	5	22	5	—			
Northern Colorado, U of	1	4	0	0			
Northern Illinois U	9	15	10	11			
Northern Iowa, U of	10	13	0	—			
Northern Kentucky U	2	3	—	—			
Northern Michigan U	1	13	0	—			
Northwest Missouri State U	3	1	—	—			
Northwestern State U of Louisiana	2	0	—	—			
Northwestern U	8	11	25	15	26	10	6
Notre Dame, U of	2	13	8	18	22	7	6
Oakland U	5	2	1	1			
Oberlin C	4	20	—	—			
Occidental C	10	10	—	—			
Ohio Northern U	10	4	—	—			
Ohio State U	31	0	17	47	35	13	4
Ohio U	3	11	6	3	11	2	1
Ohio Wesleyan U	0	7	—	—			
Oklahoma State U	2	3	3	7	16	7	4
Oklahoma, U of	11	10	9	9	23	10	5
Old Dominion U	3	4	5	3			
Oregon State U	12	2	3	13	14	7	0
Oregon, U of	6	22	1	11			
Pace U							
New York	0	0	—	—			
Pleasantville	0	5	—	—			
Pacific Lutheran U	3	4	—	—			

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelors certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Pacific, U of the	0	8	3	2			
Pennsylvania State U	10	27	4	37	87	14	11
Pennsylvania, U of	6	15	11	17	18	10	8
Philadelphia C of Pharmacy & Science	1	6	0	0			
Philadelphia C of Textiles & Science	2	0	—	—			
Pittsburg State U	1	2	3	—			
Pittsburgh, U of	20	49	2	25	28	10	9
Polytechnic U	2	0	4	14	a		
Pomona C	0	10	—	—			
Portland State U	11	11	0	5			
Portland, U of	0	0	—	—			
Pratt Institute[b]					1	—	—
Princeton U	10	9	0	11	22	2	12
Providence C	1	7	0	0			
Puerto Rico, U of							
Mayaguez	7	9	8	—	68	7	—
Rio Piedras	8	19	3	5			
Puget Sound, U of	5	4	—	—			
Purdue U	12	19	11	37	108	10	20
Purdue U Calumet	3	1	—	—			
Ramapo C of New Jersey	0	5	—	—			
Randolph-Macon C	1	4	—	—			
Randolph-Macon Woman's C	1	2	—	—			
Redlands, U of	1	4	—	—			
Reed C	7	8	—	—			
Rensselaer Polytechnic Inst	22	0	9	13	27	7	9
Rhode Island C	2	5	—	—			
Rhode Island, U of	1	1	3	7	17	8	1
Rhodes C	6	12	—	—			
Rice U	6	8	8	11	12	4	9
Richmond, U of	5	19	—	—			
Rider C	4	0	—	—			
Ripon C	3	1	—	—			
Roanoke C	1	3	—	—			
Rochester Institute of Tech	3	9	8	—			
Rochester, U of	10	5	25	18	21	10	5
Rockhurst C	3	1	—	—			
Rollins C	2	0	—	—			
Roosevelt U	3	0	4	—			
Rose-Hulman Institute of Tech	4	0	—	—	30	0	—
Russell Sage C	1	1	—	—			
Rutgers U							
Camden C of Arts & Science	2	5	—	—			
New Brunswick Dept. of Chemistry	16	25	14	12	28	8	9
Newark College of Arts & Sciences	7	7	6	4			
St. Anselm C	2	2	—	—			
St. Catherine, C of	2	3	—	—			
St. Cloud State U	6	5	—	—			
St. John Fisher C	1	1	—	—			
St. John's U/C of St. Benedict	6	14	—	—			
St. John's U	2	2	1	—			
St. Joseph C	4	2	2	—			
St. Joseph's U	10	6	7	—			
St. Lawrence U	2	4	—	—			
St. Louis U	4	7	8	—			
St. Mary's C	1	5	—	—			
St. Michael's C	0	2	—	—			
St. Olaf C	9	42	—	—			
St. Peter's C	0	3	—	—			
St. Thomas, U of	3	10	—	—			
St. Vincent C[d]	3	5	—	—			
Saginaw Valley State U	2	7	—	—			
Salem State C	3	0	—	—			
Sam Houston State U	2	2	2	—			
San Diego State U	13	0	10	4			
San Francisco State U	2	22	5	—			
San Francisco, U of	1	4	4	—			
San Jose State U	9	20	11	—	a		
Sangamon State U	4	0	—	—			
Santa Clara U	2	4	—	—			
Scranton, U of	3	8	6	—			
Seattle U	0	2	—	—			
Seton Hall U	5	5	11	7			
Seton Hill C[d]	0	1	—	—			
Shippensburg U	4	5	2	—			
Siena C	6	0	—	—			
Simmons C	1	2	—	—			
Skidmore C	0	9	—	—			
Smith C	0	4	—	—			
Sonoma State U	2	11	—	—			

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelors certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
South Alabama, U of[b]					7	2	—
South Carolina, U of	3	16	4	29	30	5	3
South Dakota School of Mines & Tech	3	1	1	—	25	3	—
South Dakota State U	1	30	8	0			
South Dakota, U of	1	3	1	—			
South Florida, U of	15	23	2	3	14	2	2
Southeast Missouri State U	3	4	—	—			
Southeastern Louisiana U	1	0	—	—			
Southern California, U of	9	2	4	22	12	14	7
Southern Colorado U	0	2	0	—			
Southern Illinois U							
Carbondale	10	0	6	4			
Edwardsville	11	12	6	—			
Southern Methodist U	5	7	0	—			
Southern Mississippi, U of	1	24	2	5			
Southern Oregon State C	2	3	—	—			
Southern U and A&M C	3	5	2	—			
Southwest Missouri State U	1	9	—	—			
Southwest State U	3	11	—	—			
Southwest Texas State U	8	0	5	—			
Southwestern Louisiana, U of	0	6	0	—	6	3	—
Southwestern Oklahoma State U	2	10	—	—			
Stanford U	7	6	8	33	21	10	11
State U of New York							
Albany	11	0	1	3			
Binghamton	7	11	1	6			
Buffalo	22	8	3	19	20	9	10
Stony Brook	11	17	9	24			
C at Brockport	3	7	—	—			
C at Buffalo	0	6	1	—			
C at Cortland	0	3	—	—			
C at Fredonia	4	3	0	—			
C at Geneseo	6	4	—	—			
C at New Paltz	1	4	0	—			
C at Oneonta	0	8	—	—			
C at Oswego	13	5	6	—			
C at Plattsburgh	5	5	1	—			
C at Potsdam	4	2	—	—			
C at Purchase	0	4	—	—			
Stephen F. Austin State U	3	5	2	—			
Stetson U	2	5	—	—			
Stevens Institute of Tech	5	0	9	3	9	10	5
Stockton State C	5	6	—	—			
Suffolk U	2	0	—	—			
Susquehanna U	2	4	—	—			
Swarthmore C	6	4	—	—			
Syracuse U	3	5	3	8	11	10	7
Temple U	9	0	2	3			
Tennessee Technological U	4	5	2	—	15	1	0
Tennessee, U of							
Chattanooga	10	14	—	—			
Knoxville	2	10	6	13	27	8	6
Martin	1	9	—	—			
Texas A&I U	6	0	0	—	a		
Texas A&M U	21	15	7	39	61	16	14
Texas Christian U	4	5	1	2			
Texas Southern U	4	0	8	—			
Texas Tech U	20	8	5	8	a		
Texas Woman's U	1	8	0	—			
Texas, U of							
Arlington	4	17	8	7			
Austin	69	0	12	42	70	18	29
Dallas	5	0	4	3			
El Paso	6	0	5	—			
Thiel C	1	1	—	—			
Thomas More C	4	0	—	—			
Toledo, U of	2	4	6	2	10	4	1
Towson State U	4	8	—	—			
Trenton State C	7	0	—	—			
Tri-State U[b]					6	—	—
Trinity C	4	0	0	—			
Trinity U	7	4	—	—			
Tufts U	0	12	8	9	18	8	4
Tulane U	1	13	1	3	a		
Tulsa, U of	9	0	—	—	a		
Tuskegee U	0	4	0	—	a		
Union C	3	4	—	—			
U.S. Air Force Academy	18	0	—	—			
U.S. Naval Academy	14	0	—	—			
Ursinus C	6	8	—	—			
Utah State U	10	0	2	1			
Utah, U of	3	33	6	20	13	5	3
Valparaiso U	2	25	—	—			
Vanderbilt U	2	26	7	7	12	6	2
Vassar C	1	4	0	—			
Vermont, U of	7	0	2	4			
Villanova U	10	0	7	2	14	5	—
Virginia Commonwealth U	5	19	1	8			
Virginia Military Institute	2	0	—	—			
Virginia Poly Institute & State U	9	12	14	14	43	4	3
Virginia, U of	9	66	3	16	16	16	8
Wabash C	8	12	—	—			
Wagner C	1	0	—	—			
Wake Forest U	8	15	1	0			
Washburn U	2	4	—	—			
Washington C	1	0	—	—			
Washington State U	5	3	2	3	19	7	5
Washington U	8	5	10	12	15	12	3
Washington, U of	34	19	17	36	52	4	14
Washington & Jefferson C	3	10	—	—			
Washington & Lee U	0	7	—	—			
Wayne State U	15	16	6	16	12	8	3
Waynesburg C	6	0	—	—			
Weber State C	7	3	—	—			
Wellesley C	2	20	—	—			
Wesleyan U	1	7	0	3			
West Chester U	5	14	6	—			
West Florida, U of	10	3	—	—			
West Virginia Institute of Tech[b]					5	4	0
West Virginia State C	0	4	—	—			
West Virginia U	4	14	2	3	10	6	3
Western Illinois U	0	8	1	—			
Western Kentucky U	2	29	4	—			
Western Maryland C	0	2	—	—			
Western Michigan U	2	16	0	1			
Western New England C	0	0	—	—			
Western Washington U	4	7	4	—			
Westminster C	0	2	—	—			
Wheaton C							
Illinois	5	8	—	—			
Massachusetts	0	1	—	—			
Whitman C	1	5	—	—			
Whittier C	0	3	—	—			
Wichita State U	8	13	4	3			
Widener U	0	1	—	—	11	—	—
Wilkes U	0	2	—	—			
Willamette U	2	11	—	—			
William Paterson C of N.J.	0	4	—	—			
William and Mary, C of	41	5	4	—			
Williams C	1	22	—	—			
Winona State U	2	0	—	—			
Wisconsin, U of							
Eau Claire	9	6	—	—			
Green Bay	1	9	—	—			
LaCrosse	4	12	—	—			
Madison	27	6	9	29	72	12	16
Milwaukee	1	14	7	3			
Oshkosh	5	3	—	—			
Parkside	2	7	—	—			
Platteville	0	5	—	—			
River Falls	10	10	—	—			
Stevens Point	8	7	—	—			
Superior	2	0	—	—			
Wittenberg U	3	6	—	—			
Wooster, C of	6	14	—	—			
Worcester Polytechnic Institute	0	4	1	0	33	3	3
Wright State U	14	6	10	—			
Wyoming, U of	6	3	2	7	6	3	1
Xavier U	3	4	—	—			
Xavier U of Louisiana	4	31	—	—			
Yale U	0	16	13	21	a		
Youngstown State U	4	26	0	—	21	—	—
TOTALS	3310	4562	1600	2213	3081	816	602

Note: For brevity, "B.S." and "M.S." are used to denote all bachelor's and master's degrees, respectively, in each column. **a** Data not submitted. **b** Listed on basis of accreditation by AIChE-ABET. **c** The chemistry programs at Mount Saint Vincent and Manhattan College are integrated into a combined department with instruction in chemistry located at Manhattan College. **d** Saint Vincent College and Seton Hill College are integrated into a combined department. **e** UNC, Chapel Hill, Applied Curriculum in Chemistry degrees are combined with the chemistry department degrees.

Illinois, Berkeley top producers of chemists

The University of Illinois, Urbana-Champaign; Cornell University; and the University of California, Berkeley, were, in that order, the largest producers of new bachelor's, master's, and Ph.D. chemists in the 1990–91 academic year.

Last year also saw the stemming of a seven-year decline in the total number of new bachelor's degree chemists with 7872 such graduates, up almost 3% from 7650 in 1989–90. As recently as 1984–85, however, there were 9679 new bachelor's degree chemists.

These are some of the salient points contained in the latest report of ACS's Committee on Professional Training. This committee gathers graduation data annually from chemistry departments with undergraduate programs it has approved. These departments account for about 95% of all new bachelor's degree chemists and for essentially all advanced chemistry degrees.

Indiana University, Bloomington, the largest producer of bachelor-level chemists in the previous six years, dropped to second in 1990–91, behind Illinois. The University of California, Los Angeles, hung onto the third spot.

Cornell University was the largest producer of master's chemistry graduates in both 1989–90 and 1990–91. The University of Michigan, Ann Arbor, moved to second last year from ninth a year earlier.

Last year was the seventh year in a row that Berkeley headed the list of Ph.D. producers. Iowa State was a strong second, moving up from seventh place.

The University of Texas, Austin, and Urbana-Champaign last year retained their number one and two spots as the largest producers of certified bachelor's graduates. These graduates are immediately eligible for ACS membership.

Five schools appear on the lists of top producers of bachelor's, certified bachelor's, master's, and doctoral chemists. They are the University of California, San Diego; University of Michigan, Ann Arbor; University of North Carolina, Chapel Hill; University of Texas, Austin; and the University of Washington.

Michael Heylin

These schools had the most chemistry graduates, 1990-91

Total bachelor graduates		
1.	U of Illinois, Urbana-Champaign	138
2.	Indiana U, Bloomington	117
3.	U of California, Los Angeles	103
4.	U of Virginia	75
5.	North Carolina State U	73
6.	U of North Carolina, Chapel Hill	71
7.	U of Pittsburgh	69
7.	U of Texas, Austin	69
9.	U of California, San Diego	56
9.	U of Maryland, College Park	56
11.	U of Michigan, Ann Arbor	55
12.	U of California, Berkeley	54
13.	U of Washington	53
14.	U of Illinois, Chicago	51
14.	St. Olaf C	51
16.	U of Colorado, Boulder	48
17.	C of William & Mary	46
18.	Cornell U	45
19.	U of Minnesota, Minneapolis	43
20.	U of California, Davis	42
21.	U of Delaware	41
21.	Miami U	41
21.	Rutgers U, New Brunswick	41
24.	New York U	40
25	Michigan State U	38
25.	U of South Florida	38

Certified bachelor graduates		
1.	U of Texas, Austin	69
2.	U of Illinois, Urbana-Champaign	62
3.	U of California, San Diego	56
4.	U of Michigan, Ann Arbor	55
5.	U of Minnesota, Minneapolis	43
6.	C of William & Mary	41
7.	U of Washington	34
8.	U of California, Davis	33
8.	Illinois State U	33
10.	North Carolina State U	32
11.	Ohio State U	31
12.	Georgia Inst of Tech	29
13.	U of California, Berkeley	28
14.	U of North Carolina, Chapel Hill	27
14.	U of Wisconsin, Madison	27
16.	U of Delaware	26
16.	Harvard U	26
16.	Youngstown State U	26
19.	Indiana U, Bloomington	23
19.	Massachusetts Inst of Tech	23
21.	U of Akron	22
21.	Rensselaer Polytechnic Inst	22
21.	State U of New York, Buffalo	22
24.	U of Cincinnati	21
24.	Texas A&M U	21

Master graduates		
1.	Cornell U	33
2.	U of Michigan, Ann Arbor	32
3.	New York U	25
3.	Northwestern U	25
3.	U of Rochester	25
6.	U of Cincinnati	19
6.	City U New York, City C	19
8.	U of California, Irvine	17
8.	Ohio State U	17
8.	U of Washington	17
11.	Columbia U	16
11.	Georgetown U	16
11.	Harvard U	16
11.	U of Illinois, Chicago	16
15.	U of California, Los Angeles	15
15.	U of California, San Diego	15
17.	Rutgers U, New Brunswick	14
17	Virginia Poly Inst & State U	14
19.	California State U, Long Beach	13
19.	U of Chicago	13
19.	Clarkson U	13
19.	Yale U	13
23.	Johns Hopkins U	12
23.	U of North Carolina, Chapel Hill	12
23.	U of Texas, Austin	12

Doctoral graduates		
1.	U of California, Berkeley	55
2.	Iowa State U	53
3.	U of Illinois, Urbana-Champaign	51
4.	Ohio State U	47
5.	City U New York, Graduate Center	42
5.	U of Texas, Austin	42
7.	Massachusetts Inst of Tech	39
7.	U of North Carolina, Chapel Hill	39
7.	Texas A&M U	39
10.	U of California, Los Angeles	37
10.	Pennsylvania State U	37
10.	Purdue U	37
13.	U of Washington	36
14.	Stanford U	33
15.	U of California, Davis	31
15.	U of Florida	31
17.	U of Cincinnati	29
17.	U of Michigan, Ann Arbor	29
17.	U of South Carolina	29
17.	U of Wisconsin, Madison	29
21.	U of Arizona	28
21.	U of Maryland, College Park	28
21.	U of Minnesota, Minneapolis	28
24.	U of California, San Diego	26
24.	Indiana U, Bloomington	26

CHEMICAL & ENGINEERING NEWS

C&EN

MAY 25, 1992

HERCULES CHAIRMAN PUTS COMPANY ON MORE PROFITABLE COURSE PAGE 8

UTAH'S ROBERT W. PARRY WINS 1993 PRIESTLEY MEDAL PAGE 21

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CHEMICAL & ENGINEERING NEWS

C&EN

MAY 25, 1992

NEWS OF THE WEEK

- President Bush decides to allow companies to increase air emissions without public notice, siding with industry against EPA and irking Congress. **Page 4**
- Brazil auctions off Copesul petrochemical complex for $805 million, taking a major step in its program to privatize state-owned industries. **Page 5**
- Global cooling can be expected over the next couple years because of emissions from eruption of the Mount Pinatubo volcano in the Philippines last June. **Page 5**
- NASA successfully carries out first flight of new space shuttle *Endeavour*, including spectacular rescue and redeployment of communications satellite. **Page 6**
- Arnold & Mabel Beckman Foundation will give $5 million to Scripps Research Institute to support chemical research. **Page 6**

COVER: Photo by Terry D. Newfarmer

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ISSN 0009-2347

BUSINESS

Divestitures, joint ventures, other moves are in the cards at Hercules as chairman Thomas Gossage plots course to improve profitability for the troubled company. **Page 8**

Companies with environmental policies that go beyond compliance with government guidelines are focus of World Resources Institute book. **Page 11**

Continued vitality of U.S. biotechnology industry is dependent on healthy technology exchange program with Japan, according to National Research Council report. **Page 11**

British Petroleum's chemicals unit launches "open communications" program aimed at garnering public trust. **Page 12**

GOVERNMENT

Research and development projects face funding cuts as Congress and Administration tussle over what is and isn't necessary in fiscal 1992 budget. **Page 14**

National and international groups are developing tighter controls, faster phaseouts for ozone-depleting compounds. **Page 16**

House bill would append pollution research funds to Resource Conservation & Recovery Act's reauthorization. **Page 16**

SCIENCE/TECHNOLOGY

Ethylene producers turn to revamping to increase production capacity and still retain capital cost advantages. **Page 18**

Carbon nitride, β-C_3N_4, developed by researchers at Northwestern University, may be harder than diamond. **Page 20**

BOOKS

Tug-of-war between cold fusion skeptics and believers continues, with nuclear chemist John Huizenga explaining his disbelief in latest book on the subject. **Page 23**

ACS NEWS

Second set of 1992 Petroleum Research Foundation grants has been approved by the ACS Board, adding $4.03 million to PRF commitments for this year. **Page 25**

PRIESTLEY MEDAL

Robert W. Parry, distinguished professor of chemistry at the University of Utah, will receive ACS's 1993 Priestley Medal in recognition of his contributions to chemical research and education and his service to the society. Page 21

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1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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(For list of offices see page 39)

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LETTERS

Global warming

In your editorial on global warming (C&EN, April 27, page 3), you state, "Over the past 10,000 years average global temperature has never been more than about 1 °C warmer or cooler than it is today."

Why limit yourself to 10,000 years? Twenty thousand years ago, North America down to the latitude of the present New York City was covered by ice thousands of feet thick. In the past million years, a short time by geological standards, there have been repeated glacial episodes separated by relatively short interglacial stages. Considering that the average interglacial stage has not been longer than about 12,000 or 15,000 years, we may well be near the end of the present interglacial interval. If so, any greenhouse effect may be a blessing, not a curse. A degree or two of warming should be better than half the world covered by ice.

Studies of the greenhouse effect all seem to assume that it is the only cause of climatic change; that without the effect the climate would remain forever as it is today in this best of all possible worlds. A very improbable base for setting world economic policy.

George Gibson
Upper Montclair, N.J.

Synthesis of RDX

I believe an error regarding the synthesis of the high explosive RDX, also known as cyclonite, appeared in Stephen Stinson's obituary of John Sheehan (C&EN, March 30, page 6). The improved method for producing RDX was the invention of Werner E. Bachmann (1901–51).

In the fall of 1940, a group of organic chemists met with Roger Adams at the University of Illinois under the aegis of the National Defense Research Committee to discuss how best to contribute to the war effort. Bachmann (University of Michigan) was assigned the problem of devising a better synthesis of RDX. Sheehan, who had just finished his doctoral thesis under Bachmann, joined the RDX project in January 1941. During the following months, Bachmann invented the "combination process" in which 2 moles of RDX are formed from 1 mole of hexamine (U.S. Patent 2,798,870). Sheehan, as Bachmann's junior colleague, made active and important contributions to this research.

For his synthesis of RDX, Bachmann was given the Naval Ordnance Award in 1945, and in 1948 was granted the Presidential Certificate of Merit, and, from the British government, the King's Medal.

As a lifelong friend of Sheehan's and as a friend and colleague of Bachmann's, my knowledge of this history is firsthand. When in October 1941 Sheehan left Michigan to go with Merck & Co., I joined Bachmann in continuing his investigation of the chemistry of RDX.

E. L. Jenner
Wilmington, Del.

Calibrating thermometers

An informative article by Richard A. Houghton and George M. Woodwell in *Scientific American* [**260,** 36 (1989)] compares three indirect global thermometers applied to the 2000-meter-deep Vostok ice core from Antarctica, dating back 160,000 years into prehistory. The hydrogen/deuterium ratio, the $^{18}O/^{16}O$ ratio, and the percentage of CO_2 in entrapped air bubbles have all been used to estimate the long-term time dependence of global temperature.

Hydrogen and oxygen isotope ratios have been used to calibrate atmospheric CO_2 as a secondary global thermometer. Since the CO_2 deposited in Antarctica has always had to come primarily from other parts of the globe where things were growing, it does not represent temperatures in Antarctica. It does not represent temperatures on high mountaintops, or in the north polar regions, or even in the vast deserts of the globe, even though

Letters to the Editor

C&EN encourages readers to contribute to this letters section. However, please keep letters reasonably short—400 words or fewer. Because we receive a heavy volume of letters, persons writing letters are limited, as a general rule, to one letter within any given six-month period.

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Second Set of 1992 ACS-PRF Grants Approved

Acting on recommendations from the February meeting of the Petroleum Research Fund advisory board, the ACS Board of Directors has approved 147 new or continuing ACS-PRF grants-in-aid. Thirty-four of the grants include a supplement of $3000 to involve an undergraduate student in the research. The board's action adds $4,039,646 to PRF commitments for 1992.

The new grants were recommended by the PRF advisory board from a total of 400 proposals. A third and final set of 1992 PRF grants will be announced this summer. Proposals for 1993 PRF grants are now being accepted. Applicants should note that the maximum values for ACS-PRF grants in 1993 have been increased as follows: Type AC grants, $25,000 per year for up to three years; Type B grants, $25,000 over two years; and Type G grants, $20,000 over two years. Also, the maximum salary and benefits that the principal investigator may receive each year is $5000; the annual limit for travel is $1000. Applicants from Ph.D. departments may request a $3000 supplement to involve an undergraduate in the research.

The "36th Annual Report on Research Under Sponsorship of the Petroleum Research Fund" will be available in May. Individuals who wish a complimentary copy, or information and application forms for current ACS-PRF grant programs, should write to Petroleum Research Fund, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036, or call (202) 872-4481.

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type AC)

Richard D. Adams, U of South Carolina. Studies of the Coordination and Ring-Opening Reactions of Strained-Ring Thioethers with Metal Carbonyl Cluster Complexes. $40,000

William C. Agosta, Rockefeller U. Abstraction of Hydrogen by Nitrogen and Oxygen in Heteroaromatic Ketones. $40,000

Steven R. Angle, U of California, Riverside. Enantioselective Synthesis of Pipecolic Acids. $40,000

Steven M. Bachrach, Northern Illinois U. Electron Density Analysis of Organic Reaction Mechanisms. $40,000

Ian Baker, Dartmouth C. Synchrotron X-Ray Topographic Study of Deformation in Polycrystalline Ice. $37,136

John L. Belletire, U of Cincinnati. Strained-Ring Heterocyclic Targets via Free-Radical Cyclization. $43,000

Brian E. Bent, Columbia U. Carbon-Carbon Bond Formation on Copper Surfaces. $63,000

Richard Bersohn, Columbia U. Tests of Mode-Selective Chemistry in Polyatomic Molecules. $40,000

Silvio E. Biali, Hebrew U of Jerusalem. Stereochemistry of Polysubstituted Cyclohexanes. $40,000

Neal E. Blair, North Carolina State U. The Intramolecular Carbon Isotopic Composition of Amino Acids in the Marine Environment. $43,000

Jennifer S. Brodbelt, U of Texas, Austin. Host-Guest Chemistry in the Gas Phase. $40,000

Barry K. Carpenter, Cornell U. Control of Selectivity through Cosolvent Design. $40,000

Peggy Cebe, Massachusetts Inst. of Technology. Relaxation of the Crystal-Amorphous Interphase in Polymer Blends. $40,000

John S. Compton, U of South Florida, St. Petersburg. Deposition and Alteration of Volcanic Material in the Monterey Formation, California. $40,000

Robert E. Criss, U of California, Davis. Stable Isotope Study of Perennial Saline Springs Related to Abnormally High Fluid Pressures and Active Thrusting in the Western Sacramento Valley, California. $40,000

M. David Curtis, U of Michigan. Covalent Organotransition Metal Polymers. $43,000

Robert H. Davis, U of Colorado. The Nature and Effects of Contact Forces Involving Solid Particles in Fluids. $43,000

J. Paul Devlin, Oklahoma State U. Dynamics at Ice Surfaces: Spectra of Adsorbed Small Molecules. $43,000

Rudiger Dieckmann, Cornell U. Demixing of Doped Zirconia in Potential Gradients. $43,000

Paul E. Dietze, U of Maryland, Baltimore County. Solvolysis of Silyl Ethers. $40,000

Steven G. Driese, Claudia I. Mora, U of Tennessee. Stable Isotope Composition of Pedogenic Carbonate in Central and Southern Appalachian Red-Bed Sequences: Monitor of Elevated P_{CO_2} during the Paleozoic? $43,000

Paul L. Dubin, Indiana U-Purdue U, Indianapolis. Polyelectrolyte-Protein Complexes. $40,000

Sandra S. Eaton, U of Denver, Colorado Seminary. EPR of C_{60} Radicals. $43,000

Irving R. Epstein, Brandeis U. Design and Analysis of Turing Structures in Reaction-Diffusion Systems. $40,000

Glenn T. Evans, Oregon State U. Dynamics in Liquid Crystals. $40,000

Graham R. Fleming, U of Chicago. Chemical Dynamics Probed with Phase-Locked Femtosecond Pulses. $40,000

Roger Frech, U of Oklahoma. Ionic Association in Polymer-Salt Complexes: Effect of Chain Length and Plasticizers. $40,000

Robert E. Garrison, U of California, Santa Cruz. Shelfal Sedimentary Processes and Cycles in a Miocene Upwelling Environment. $43,000

Alice P. Gast, Stanford U. The Structure of Adsorbed Block Copolymers in Flow. $40,000

Richard S. Givens, U of Kansas. Mechanistic and Exploratory Investigations of Hydroperoxyester-Induced Chemiluminescence. $43,000

Timothy Halpin-Healy, Barnard C. Investigations into the Self-Affine Fractal Geometry of Nature, as Revealed in Condensed Matter Physics. $40,000

Eric J. Heller, U of Washington. Semiclassical Investigations of Molecular Spectroscopy. $40,000

Reinhard Hesse, McGill U. Layer-Charge Development and Fundamental-Particle Nature of I/S Mixed-Layer Clays during Progressive Burial Diagenesis in Beaufort-MacKenzie Basin: HRTEM Study. $40,000

David A. Hoagland, U of Massachusetts. A Study of Flow-Induced Fracture of Polymer Chains by Gel Electrophoresis. $40,000

Catherine E. Housecroft, U of Cambridge. Multiruthenaboranes as Precursors in Organometallic Chemistry and to Linked and Fused Clusters. $40,000

W. Phillip Huskey, Rutgers U. Characterization of Solvation Changes Accompanying Proton Transfer from Carbon. $40,000

Clark M. Johnson, U of Wisconsin, Madison. U-Pb Age Determinations of Carbonate Diagenesis in the Michigan Basin and on the Wisconsin Arch. $40,000

Brent Koplitz, Tulane U. Site-Specific Photochemistry Involving Organic and Metalorganic Systems. $40,000

Mary J. Kraus, U of Colorado. Floodplain Deposition, Pedogenesis, and Shallow Burial Diagenesis in the Lower Mississippi River Valley. $40,000

Robert L. Kuczkowski, U of Michigan. Weak Complexes of Sulfur Dioxide. $40,000

Sanat K. Kumar, Pennsylvania State U. Calculation of the Gibbs Free Energy of Polymeric Systems from Simulations. $40,000

Koop Lammertsma, U of Alabama, Birmingham. A Reactivity-Selectivity Study of Phosphinidenes. $40,000

John W. Larsen, Lehigh U. Macromolecular Structure of Type I and II Kerogen. $40,000

Kenneth R. Leopold, U of Minnesota. Microwave Studies of the Transition from van der Waals to Covalent Bonding. $40,000

C. Peter Lillya, U of Massachusetts. An Experimental Study of the Statics and Dynamics of Discotic Nematic Liquid Crystals. $40,000

George Majetich, U of Georgia. New Allylsilane-Based Annulation Strategies. $43,000

Murli H. Manghnani, U of Hawaii, Manoa. Laboratory Study of the Elastic and Anelastic Properties of Reservoir Rocks: Emphasis on Carbonate Rocks. $40,000

Ursula Mazur, Kerry W. Hipps, Washington State U. Resonant Tunneling in Metal Phthalocyanines: an Experimental Study. $43,000

Mark L. McLaughlin, Louisiana State U. Diene-Metallocene Polymers from Ring-Opening Metathesis Polymerization. $40,000

David R. McMillin, Purdue U. Understanding Blue Copper Oxidases and the Catalytic Reduction of Dioxygen. $43,000

William E. McMullen, Texas A&M U. Density Functional Theories of Polymer Interfaces. $40,000

Donald F. McNeill, U of Miami, RSMAS. Magnetostratigraphic Dating Constraints on Sea-Level and Seismic Reflector Synchroneity in Carbonate Platform and Slope Settings: Bahamas Drilling Project Cores. $40,000

John H. Nelson, U of Nevada, Reno. Transition Metal Promoted Reactions of Coordinated Phosphines. $43,000

Cheuk-Yiu Ng, Iowa State U. Photoionization and Photoelectron-Photoion Coincidence Studies of Transition Metal Carbonyls and Their Fragments. $40,000

Amos M. Nur, Stanford U. Source Rock, Maturation-Induced Cracks, and Seismic Mapping. $40,000

James S. Panek, Boston U. Asymmetric Synthesis with Optically Active α-Substituted β-Silyl-Hex-4-Enoates. $43,000

Sidney Redner, Boston U. Kinetics of Lattice Models of Catalysis. $40,000

Arnold L. Rheingold, U of Delaware. Diphosphenes and Diarsenes in Cluster Synthesis: Preparation of Metal/Main-Group Multiple Bonds. $40,000

James A. Saunders, Auburn U. Reaction-Path Modeling of Intrabasin Chemical Evolution of Oil-Field Brines. $35,600

John G. Sclater, U of California, San Diego. The Implication of Heat Flow Anomalies for the Temperature and Geometry of Salt Structures on the Texas Continental Slope, Gulf of Mexico. $39,935

Kenneth Showalter, West Virginia U. Spatiotemporal Behavior in Chemical Systems. $43,000

Mark A. Smith, U of Arizona. Temperature-Dependent Free-Radical Kinetics between 20 and 200 K. $43,000

Alan D. Sokal, New York U. New Numerical Methods for Polymer Simulations. $40,000

Roger G. Tobin, Michigan State U. Adsorption and Dissociation on Stepped Metal Surfaces. $40,000

Veronica Vaida, U of Colorado. Spectroscopy and Photoreactivity of Ozone Heteroclusters. $40,000

John G. Verkade, Iowa State U. New Chemistry of Novel Four- and Five-Coordinate Main Group Compounds. $40,000

Robert M. Waymouth, Stanford U. Mechanism of Catalytic Olefin/Grignard Cross-Coupling and Diene Cyclization Reactions. $40,000

Paul Weimer, U of Colorado. An Integrated Sequence Stratigraphic Study of Neogene Turbidite Systems, Northern Gulf of Mexico. $40,000

Mark E. Welker, Wake Forest U. Synthesis and Reaction Chemistry of 2-Transition-Metal-Substituted 1,3-Diene Complexes. $43,000

James R. Wood, Michigan Technological U. Geochemical Signatures of Cements in Sands and Fractures, Elk Hills, California: Implications for Large-Scale Transport. $43,000

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type B)

Christopher J. Abelt, C of William & Mary. Diversion of Benzophenone Photochemistry to Isotoluene Enol Intermediates. $20,000

Alan M. Bailey, U of Southwestern Louisiana. Compositional Variation of Solutions Expelled from Peats during Laboratory Coalification. $20,000

Richard N. Biagioni, Southwest Missouri State U. Chemistry of Hexahapto Indenyl and Fluorenyl Transition Metal Complexes. $20,000

Susan T. Collins, California State U, Northridge. Matrix-Isolation Studies of Excited-State Proton-Transfer Systems. $20,000

Stephen L. Davis, George Mason U. Theoretical Investigations of Collisional Excitation in Nonrigid Molecules. $20,000

Thomas E. Goodwin, Hendrix C. New Synthetic Transformations of 3-Bromo-2-Methoxypropene. $20,000

Fred J. Grieman, Pomona C. Electronic Spectroscopy of Organometallic Cations. $20,000

Norris W. Hoffman, U of South Alabama. Low-Valent Fluoro, Acetato, and Chloro Complexes of Coordinatively Saturated d^4, d^8, and d^{10} Species. $20,000

Narayan S. Hosmane, Southern Methodist U. Novel Metallacarboranes of "Carbons Adjacent" and "Carbons Apart" C_2B_4-Carborane Systems. $20,000

Richard H. Judge, U of Wisconsin, Parkside. Rotational Analysis of the Singlet-Triplet Spectrum of Selenoformaldehyde, CH_2Se. $20,000

Aldo D. Migone, Southern Illinois U, Carbondale. Adsorption Studies of Simple Molecules on Boron Nitride. $20,000

Neal R. O'Brien, State U of New York, Potsdam. The Periodicity and Causes of Lamination in Shale. $19,975

D. Jeffrey Over, State U of New York, C at Geneseo. Depositional History, Biostratigraphy, and the Frasnian-Famennian Boundary of the Middle-Late Upper Devonian Marine Clastic Sequence in the Central and Northern Appalachian Basin. $20,000

Rabindra N. Roy, Drury C. Thermodynamic Study of Electrolyte Mixtures. $20,000

Ronald R. Ruminski, U of Colorado, Colorado Springs. Synthesis and Characterization of Low-Spin d^6 Metal Complexes Bound through the Bridging Ligand Dipyrido(2,3-a:2′,3′-h)phenazine. $20,000

Allen M. Schoffstall, U of Colorado, Colorado Springs. Intramolecular 1,3-Dipolar Cycloadditions in Synthesis of Sugar Derivatives. $20,000

Greg A. Slough, C of Wooster. Catalytic Cyclization of *N*-Acyl-Phenylsulfonamides. $20,000

James N. Spencer, Claude H. Yoder, Franklin & Marshall C. A Structural and Thermodynamic Study of Lewis Interactions in Host-Guest Complexation Reactions. $20,000

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type G)

John V. Badding, Pennsylvania State U. High-Pressure Chemistry of Alkali and Alkaline Earth Metals. $18,000

David A. Becker, Virginia Polytechnic Inst. & State U. Isoxazole-Methylene Aziridine Rearrangement: Synthesis and Chemistry of an Unusual Class of Functionalized Enamines. $18,000

David Deming, U of Oklahoma. Thermal History of Sedimentary Basins. $21,000

Maya Elrick, U of New Mexico. Cyclostratigraphy and Dolomitization of Middle Devonian Carbonate Deposits, Eastern Great Basin. $18,000

George L. Gould, U of Illinois, Chicago. Chemistry of Difluoroacetylene and Fluorocarbyne Ligands. $18,000

John N. Haseltine, Georgia Inst. of Technology. Molecular Recognition of Sugars: Artificial Receptors for Monosaccharides. $21,000

Kenneth Haug, Lehigh U. A Theoretical Study of the Optical and Electrical Properties of Doped Sodalite Zeolite. $21,000

Zhibing Hu, U of North Texas. Ultrasonic and Dielectric Investigation of the Critical Phase Transition in Polymer Gels. $21,000

Rein U. Kirss, Northeastern U. α-Transmitted Electrical and Magnetic Effects in Diiron Complexes Bridged by Oligosilanes and Oligostannanes. $18,000

Prashant N. Kumta, Carnegie Mellon U. Chemical Synthesis and Structural Investigation of Ultrafine Alkoxy-Sulfide Precursors to Rare Earth Chalcogenides. $18,000

Eric C. Long, Indiana U-Purdue U, Indianapolis. Stabilization of DNA Recognition Helices through Strategically Placed Metal Binding Sites. $21,000

Frederick C. MacKintosh, U of Michigan. Effects of Composition and Orientational Order in Fluid Membranes. $18,000

Pawel Mazur, City U of New York, Hunter C. Monte Carlo Studies of the Ionic Environment Near Oligoelectrolytes. $21,000

Gordon J. Miller, Iowa State U. Transition Metal Polycompounds: Synthesis, Structure, and Bonding. $18,000

Michael J. Natan, Pennsylvania State U. Metal Nanosurfaces: Synthesis, Purification, and Surface-Enhanced Raman Scattering. $21,000

Michael Y. Ogawa, Bowling Green State U. Photoinduced Electron-Transfer across Artificial Beta-Sheets. $21,000

David A. Osleger, U of California, Riverside. Cycle/Sequence Stratigraphy of Backreef to Inner Shelf Carbonates, Seven Rivers Formation, Guadalupe Mountains, New Mexico. $18,000

Ronald J. Phillips, U of California, Davis. Hindered Diffusion in Porous and Fibrous Media. $18,000

Julianto Pranata, U of Arkansas. Computer Simulations of Chemical Reactions in Solution. $18,000

Shankar B. Rananavare, Oregon Graduate Inst. of Science & Technology. Dynamics of Fluctuating Interfaces. $21,000

Tarek Sammakia, U of Colorado. The Design of New Asymmetric Reaction Processes. $18,000

Daniel T. Schwartz, U of Washington. Electrolytic Fabrication and Testing of Nano-Structured Alloys for Corrosion-Resistant Coatings. $18,000

Eugene I. Shakhnovich, Harvard U. Towards Quantitative Theory for Protein Stability. $18,000

Lowell D. Stott, U of Southern California. An Investigation of Stable Isotopic Anomalies in Marine Organic Matter during Climate and Primary Productivity Cycles in San Pedro Basin, California Borderland. $21,000

John E. Straub, Boston U. Novel Simulation Algorithms for Conformational Sampling and Free Energy Calculations on Biomolecules and Polymers. $18,000

John B. Vincent, U of Alabama. Characterization of Low Molecular Weight Chromium-Binding Substance and Synthetic Model Complexes. $21,000

John M. Wiencek, Rutgers U. Simultaneous Separation and Polymerization of Aromatics by a Bienzymatically Catalyzed Membrane Reactor. $21,000

E. Wrenn Wooten, U of Michigan. Structure and Dynamics of Oligosaccharides and Glycoproteins. $21,000

Charles K. Zercher, U of New Hampshire. Synthetic and Conformational Studies of Polycyclopropanes. $21,000

Kenneth M. Beck, U of Central Florida. Dynamics of Dissociation in Polycyclic Aromatic Hydrocarbons. $18,000

Frances R. Blase, Haverford C. Use of β-Keto σ-Dioxolane Sulfoxides for Stereoselective Reactions. $18,000

Xiangning Chen, U of Nebraska, Kearney. Singlet Oxidation of Substituted 7-Thiabicyclo[2.2.1]heptanes. $18,000

Thomas D. Getman, Southern Illinois U, Edwardsville. Precursors to Group III(13) Nitrides. $18,000

Karen Grove, San Francisco State U. Quaternary Sedimentation along the San Andreas Fault North of San Francisco, California. $18,000

Russell G. Kerr, Florida Atlantic U. Biosynthesis of Pregnanes in Marine Invertebrates. $18,000

Leigh C. Porter, U of Texas, El Paso. Thiophene Binding and Reactivity Studies Involving Ru and Os Transition Metal Hydrides. $18,000

James L. Sadd, Occidental C. Holocene Depositional History and Sedimentary Processes in the Mugu Lagoon-Barrier System, California. $18,000

Da-Ming Zhu, U of Missouri, Kansas City. Thermodynamic Study of Multilayer Xe Films Adsorbed on Graphite. $18,000

Marc Zimmer, Connecticut C. Model Systems for Aldehyde Ferrodoxin Oxidoreductase, a Tungsten Enzyme. $18,000

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type SE)

Tze-Chiang Chung, on behalf of the ACS Division of Polymeric Materials: Science & Engineering Inc. Recent Advances in Polyolefin Polymers, ACS national meeting, Washington, D.C., fall 1992. $2000

Joseph J. Gajewski, on behalf of the ACS Division of Organic Chemistry. James Flack Norris Award, ACS national meeting, San Francisco, spring 1992. $2000

Boualem Hammouda, on behalf of the ACS Division of Polymeric Materials: Science & Engineering Inc. Neutron Scattering from Polymers, ACS national meeting, Washington, D.C., fall 1992. $2000

Hannes Jonsson, on behalf of the ACS divisions of Colloid & Surface Chemistry and Physical Chemistry. Theoretical Aspects of Materials-Related Surface Chemistry, ACS national meeting, Washington, D.C., fall 1992. $2000

Kenneth D. Karlin, on behalf of Johns Hopkins U. Bioinorganic Copper Chemistry, Johns Hopkins U, August 1992. $2000

Howard E. Katz, on behalf of the Materials Research Society. Ordered Materials by Design, Materials Research Society Fall Meeting, Boston, November–December 1992. $2000

Jacek Lipkowski, on behalf of the ACS Division of Colloid & Surface Chemistry. The Electrical Double Layer (honoring Roger Parsons), ACS national meeting, San Francisco, spring 1992. $2000

James E. McGrath, on behalf of the ACS divisions of Polymer Chemistry Inc. and Polymeric Materials: Science & Engineering Inc. Polymer Matrix Resins for Composites, ACS national meeting, San Francisco, spring 1992. $2000

S. Ted Oyama, Joe W. Hightower, on behalf of Clarkson U. Catalytic Selective Oxidation, ACS national meeting, Washington, D.C., fall 1992. $2000

Joseph B. Schlenoff, on behalf of the ACS Division of Colloid & Surface Chemistry. Electrochemistry of Conducting Polymers, ACS national meeting, Washington, D.C., fall 1992. $2000

Russell H. Schmehl, on behalf of the ACS Division of Colloid & Surface Chemistry. Modification of Ground- and Excited-State Properties by Supramolecular Assemblies, ACS national meeting, San Francisco, spring 1992. $1500

Martin Schoell, on behalf of the ACS Division of Geochemistry Inc. Compound Specific Isotope Analysis, ACS national meeting, San Francisco, spring 1992. $2000

Bernard Shizgal, on behalf of Rarefied Gas Dynamics Symposia. Rarefied Gas Dynamics, 18th Rarefied Gas Dynamics Symposium (RGD 18), Vancouver, British Columbia, July 1992. $2000

William C. Stwalley, on behalf of U of Iowa. 8th Interdisciplinary Laser Science Conference, Albuquerque, N.M., September 1992. $2000

Gregory R. J. Thatcher, on behalf of the ACS Division of Carbohydrate Chemistry. The Anomeric Effect, ACS national meeting, Washington, D.C., fall 1992. $2000

Martha K. Turckes, on behalf of the ACS Division of Education. ACS Project SEED—Supplementary Program for Summer 1992. $22,500

Robert D. Walkup, on behalf of the ACS South Plains Section. Organic Chemistry (A. I. Meyers Symposium) at the 48th ACS Southwest Regional Meeting, Lubbock, Tex., October 1992. $2000

Anthony J. I. Ward, on behalf of the ACS Division of Colloid & Surface Chemistry. Surfactants and Association Colloids: Solubilization Phenomena, ACS national meeting, Washington, D.C., fall 1992. $2000

Thaddeus E. Whyte Jr., on behalf of the International Zeolite Association. 9th International Zeolite Conference, Montreal, July 1992. $2000

Richard W. Zuehlke, on behalf of Gordon Research Conferences. TARP—a Teaching and Research Program, Summer 1992. $5000 ☐

New Frasch grants in agricultural chemistry

At its December 1991 meeting, the ACS Board of Directors, on recommendation of the ACS Committee on Frasch Foundation Grants, voted to recommend to the trustee 17 grants for research in agricultural chemistry. The new Frasch grants, with a total value of $1,444,246, are for a five-year period starting July 1, 1992, and are subject to yearly review of progress.

ACS advises the United States Trust Co. of New York, trustee of the Herman Frasch Foundation, on the conduct of Frasch grants for research in agricultural chemistry. The next competition for Frasch grants will be held in 1996.

John A. Browse, Washington State U. CDP-Choline: Diacylglycerol Cholinephosphotransferase: a Key Enzyme in Oilseed Lipid Metabolism. $84,246

Edward J. Brush, Tufts U. Enzyme Chemistry in the Formation and Detoxification of Cyanide in Cyanogenic Plants. $85,000

James B. Callis, U of Washington. Noninvasive Field Monitoring of Key Parameters of Plant Physiology. $85,000

Lynn Epstein, U of California, Berkeley. Regulation of Fungal Spore Germination in Soil. $85,000

James B. Gloer, U of Iowa. New Antiinsectan Compounds from Fungi. $85,000

Bruce J. Hrnjez, North Dakota State U. Enzymatic Catalysis in Supercritical Fluids: a Methodology for Production of Enhanced Value Products from Seed Oils. $85,000

David A. Lightfoot, Southern Illinois U, Carbondale. Altering Biochemical Responses of Plants to Ammonium Fertilizers and Nitrification Inhibitors. $85,000

Basil J. Nikolau, Iowa State U. The Chemistry and Biochemistry of Uncommon Plant Lipids. $85,000

Glenn D. Prestwich, Scott McN. Sieburth, State U of New York, Stony Brook. Insect Peptides: Structures, Receptors, and Mimicry. $85,000

R. Michael Roe, North Carolina State U. Transition State Inhibitors and Diagnostic Substrates for Insect Esterases Responsible for Insecticide Resistance. $85,000

Mary E. Rumpho, U of Maryland. Regulation of Chloroplast Biochemistry and Metabolite Transport. $85,000

Charles R. Sanders II, Case Western Reserve U. Structures of Phytochemically Relevant Oligosaccharides: New Methods and Concepts. $85,000

Charles E. Strouse, U of California, Los Angeles. Lattice Clathrates for the Controlled Delivery of Agricultural Chemicals. $85,000

Virginia Walbot, Stanford U. Impact of Cold Stress on Cytochrome Oxidase, Alternative Oxidase, Glycolysis, and ATP Synthesis in Maize and Rice Seedlings. $85,000

Jonathan D. Walton, Michigan State U. Evolution of a Cyclic Peptide Gene Cluster from a Fungal Maize Pathogen. $85,000

Robert M. Williams, Colorado State U. Inhibition of Lysine Biosynthesis. $85,000

Ronald W. Woodard, U of Michigan. Mechanistic Studies of 1-Aminocyclopropane-1-Carboxylic Acid Synthase: Catalysis and Inactivation. $85,000

Shutter Priority photo

Youngsters visit ACS as part of minority partnership

Students from the Kiddie Kollege program at Johnson C. Smith University (JCSU) in Charlotte, N.C., gather in front of American Chemical Society headquarters in Washington, D.C., during a visit last month as part of an ACS Education Division project funded by the Department of Education's Minority Science Improvement Program. The youngsters participated in hands-on science activities from *WonderScience* magazine under the guidance of ACS staffers. The project aims to establish five model partnerships throughout the U.S. that include an ACS local section, a federally designated minority college or university, and local industry. The program in Charlotte represents the first of these partnerships and the Kiddie Kollege at JCSU is the focus of that partnership. The other partners in Charlotte are the Charlotte-Mecklenberg school system, the Chamber of Commerce, Inroads Inc., and the ACS Piedmont Section.

Regional meeting call for papers

The ACS Washington, D.C., Section will host the Joint 26th Middle Atlantic/44th Southeastern Regional Meeting, Dec. 6–9 at the Hyatt Regency Crystal City Hotel in Arlington, Va. The program features 28 symposia and 10 workshops. Papers are solicited from high school chemistry research, technician research, inorganic chemistry, analytical chemistry, organic chemistry, biochemistry, physical chemistry, polymer chemistry, and biotechnology.

One camera-ready abstract on the standard ACS form and four copies should be submitted by July 1 to Charles F. Hammer, Department of Chemistry, Georgetown University, Washington, D.C. 20057, phone (202) 687-6170. Contributors should indicate if they prefer a poster session.

For general information about the meeting, registration, or housing, contact B. Mandava, SRS Intl., 1625 K St., N.W., Suite 1000, Washington, D.C. 20006, phone (202) 223-1424. ☐

Papers for Southwest Regional Meeting

The ACS 48th Southwest Regional Meeting will be held Oct. 21–23 in Lubbock, Tex. Papers are being solicited for general sessions in the following chemical areas: analytical/environmental, biochemistry, chemical education, organic, inorganic, and physical. Symposia to be offered include the A. I. Meyers Symposium on Organic Chemistry; Intramolecular Dynamics and Kinetics of Excited Molecules; Molecular Modeling; Reactivity and Structure of Group 6B Metal Compounds; Biological Electron Transport; Synthetic Hosts for Recognition of Molecular and Ionic Guests; Southwest Luminescence Symposium I: Theory, Dynamics, and Ap-

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CHEMICAL & ENGINEERING NEWS

C&EN

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NEWS OF THE WEEK

- Scientists at Scripps Research Institute create the first mirror-image version of a naturally occurring enzyme. **Page 4**
- Supreme Court issues two decisions that prohibit states from selectively restricting the amounts of hazardous or other waste imported into them. **Page 5**
- Witnesses debate actions proposed in technology and competitiveness act at House subcommittee hearing. **Page 5**
- Full-size replicas of two modules of NASA's space station *Freedom*, scheduled to tour the country, went on display at the U.S. Capitol. **Page 6**
- Although plastics recycling increased significantly in 1991, finding markets for recycled materials is proving to be difficult. **Page 6**

BUSINESS

Biotechnology company stock values plunged after reaching all-time highs in late 1991 and early 1992, but the market shows some signs of recovery. **Page 18**

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NIH's request to patent parts of genes has drawn cries of foul from U.S., foreign groups worried over effect such a move would have on human genome project, other research. **Page 21**

Tussle over definition of waste stream delays changes to Form R, the document companies must use to report to EPA emissions regulated by Toxics Release Inventory law. **Page 22**

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NEWS FOCUS

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Volume 70, Number 23
CENEAR 70 (23) 1–56
ISSN 0009-2347

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
(For list of offices see page 55)

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LETTERS

More credit for school projects

I would like to add some information regarding a caption (C&EN, April 20, page 56) on a photograph of schoolchildren's projects described as an "Invention Convention." The event was officially given the name "Kidvention," chosen in a contest held by the ACS Santa Clara Valley Section.

Also, several additional sponsors joined the activity: the ACS Division of Chemical Education and the College of San Mateo's math-science department. The ACS Division of Chemical Education also cooperated by supplying *Wonder Science* magazines for the participants.

Hubert E. Dubb
Chairman, ACS Committee on Patents & Related Matters

Misconduct in science

This concerns the article on misconduct in science (C&EN, April 27, page 4). The problem with recognizing and apprehending "misconduct" lies in the factors whence the phenomenon arises: failure to apply valid methodology of mathematical statistics. Far too many technologists remain under the misapprehension that a measurement result is a fact, rather than a random number.

As I am sure the editors are aware, a multitude of Gordon Research Conferences convene every summer on the West Coast, as well as at choice spots in New Hampshire. In 1951, the Conference on Statistics in Chemistry & Chemical Engineering was initiated. One of the founders (and an early chairman) was Carl A. Bennett, coauthor (with chemical engineer Norman A. Franklin of the University of Leeds) of "Statistical Analysis in Chemistry and the Chemical Industry" [John Wiley & Sons, New York (1954)]. I attended these conferences off and on for 30 years, starting in 1958. I met Bennett in 1951, about the time of the founding conference. I had gone to Hanford, Wash., to meet him and to elicit guidance about my new assignment in the atomic energy division of my then employer. We renewed our longtime acquaintance at the meeting in 1988.

As a lifelong chemical engineer (after more than 50 years, I can barely recall when I wasn't one), I am well aware that most chemical (physical, biological, medical) technologists are innocent of the hazards of drawing conclusions absent valid statistical procedures. I have worked with groups that proceed blithely performing elaborate, time-consuming measurements with no regard whatever for the consequences of attempting to repeat the result (singular). Thus, it should be no surprise that when competing (substitute whatever adjective and/or noun you prefer) chemists attempt to reproduce reported results, confusion abounds. It is difficult to separate incompetence/chicanery from the background noise.

Frank Vance
San Diego

Job interview—50 years ago

I would like to add my job interview experience to the several published in recent months. Mine goes back more than half a century.

In 1935, I received a rare response and even rarer invitation for an interview from an employer who advertised in C&EN. This was the chemical division of a nationally known manufacturer located in a New England mill town, later to be listed as a Fortune 500 company.

They wanted a control chemist at 50 cents an hour for a 40-hour week. Holidays were unpaid, but could be made up by Saturday work. In those days, you didn't ask about vacation and benefits. At the end of the interview I was told I would not be reimbursed for transportation expense, amounting to $5.00—more than a day's pay. I was also asked my religion.

On entering the plant, I was asked to give up my matches and was given a new book when I left. I didn't get the job.

Bernard Wager
New York City

Unfair to chemical industry

In this time of growing awareness toward our environment and its problems I, among many others, am glad to see that the chemistry community is changing its attitudes. However, we as chemists might want to tell this to the rest of the world.

An advertisement recently appeared

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Biotechnology Stocks Plunge From All-Time Highs

■ ***Loss of half of stock value followed peak early this year and industry's best financing year ever in 1991***

Ann M. Thayer,
C&EN Northeast News Bureau

It's been called a plunge, a correction, and a bloodbath. The nose-diving value of biotechnology stocks since the start of 1992 looks harsh, especially in the light of 1991, the most prosperous financing year in the history of the industry. The enthusiasm toward biotechnology contributed to about $4 billion being raised in 1991 stock offerings and to a market valuation in excess of $35 billion for biotechnology companies. But since reaching all-time highs in late 1991 and early 1992, biotechnology stock prices fell an average of about 50% by late April, and no company is immune, not even the industry leaders.

Amgen, the avowed biopharmaceutical champion with $680 million in revenues and $98 million in earnings in 1991, saw its stock slide downward 36%, from a high of nearly $78 per share in January to about $50 per share by late April. Similarly, stock prices for other notable companies such as Biogen, Chiron, Genzyme, and Synergen fell between 42 and 55% during the same period. Majority ownership by large pharmaceutical partners helped Genentech and Genetics Institute to some extent, since their stock values fell only 18% and 33%, respectively. However, SyStemix, owned 60% by Sandoz, was not spared as it had a 55% drop from January to April. Because biotechnology stocks are event driven, Centocor and Immune Response were hit even harder and saw prices drop about 83% and 67%, respectively, because downturns in their prospects contributed to the already negative outlook.

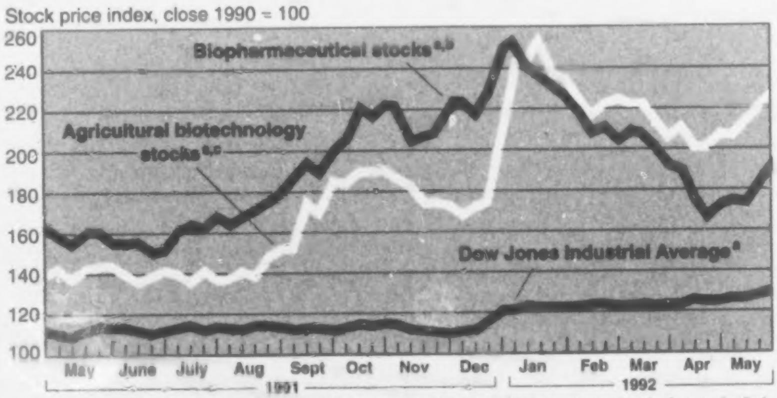
The "correction" in stock prices was not unexpected. In fact, its coming had long been anticipated. Taken as an industry, biotechnology stocks had elevated values, even though most companies had neither products nor profits. Biotechnology stocks had been riding high on the success of a few major companies and their biopharmaceutical products, and investors were looking for another Amgen or Genentech (C&EN, March 30, page 9). Companies such as MedImmune, Immune Response, and SyStemix, which had heady gains of 200 to 300% in stock values following extremely lucrative public offerings in 1991, saw stock prices come crashing down in 1992. Although their stock prices have recovered noticably, they are nowhere near their highs of the past 52-week period.

The C&EN biotechnology stock indexes—on biopharmaceuticals and agricultural companies—both rose about 200% in 1991, reaching highs of 257 (close of 1990 = 100) in January 1992. However, because biotechnology companies are measured in terms of promises and not realities, their stocks are extremely susceptible to disillusionment on the part of investors. This "speculative excess," as it is called by one analyst, set the industry up for a sharp correction in prices. Thus, as investor interest waxed, so too did it wane, and by the end of April, the biopharmaceutical index had dropped to a low of 166. Agricultural biotechnology stocks were also hit but did not drop nearly so far, with the index reaching a low of only about 200.

Investors have been taking their money out of biotechnology stocks and presumably putting it elsewhere. In comparison to the biotechnology stock indexes, the Dow Jones Industrial Average has been hovering near its all-time high for the past several weeks. Biotechnology and health care stocks had been strong in the past few years as a sector of the market with the greatest promise for growth. However, as the stock market grows, sectors other than health care once again become attractive for investment.

The remaining questions are whether biotechnology stocks will drop further or, if recovery is in store, how high they will go again. The strong biotechnology companies with products, and some with profits, have seen stock values rise

Biotech stocks turn back up after average 50% drop



[a] Reindexed to show relative change. Prices as of Friday close each week. [b] Based on stock prices for Amgen, Applied Bioscience, Biogen, Centocor, Chiron, Cytogen, Genentech, Genetics Institute, Immunex, Repligen, and Xoma. [c] Based on stock prices for Calgene, Crop Genetics, DNA Plant Technology, Ecogen, and Mycogen.

throughout May. This is reflected by the C&EN stock price index in which several of these companies are represented. Although they have not returned to their former highs, Amgen, Chiron, Genetics Institute, Gensia, Genzyme, Synergen, and Xoma have made strides toward recovering some of their stock values.

Among agricultural biotechnology companies, although the stocks have never had the market value of biopharmaceuticals, stock prices were not hit as hard and have recovered somewhat more on a percentage basis. Calgene's stock came back very strongly, buoyed by the recent position of the Food & Drug Administration on genetically engineered foods (C&EN, June 1, page 5). Mycogen, with the only two approved genetically engineered biopesticides, saw its stock price drop 31% between January and April but has since seen it rise and become relatively stable. This has made some view agricultural biotechnology, long the stepchild of the industry, as a better bet in a volatile time.

For most other companies, stock prices are lingering near or only a few dollars above their 52-week lows and much below their 52-week highs. These companies will need real results—development milestones, products, and eventually profits—to pull themselves up. In addition, along with the quantity of offerings in 1991 came questions of the quality of new companies. Whether these companies survive and warrant higher stock valuations will be a test of their scientific and management merit.

Expectations for the future are somewhat mixed as to whether biotechnology stocks will surge once again. Most analysts seem to believe that this is not likely, certainly not in the near future. Recent optimistic notes for the industry are the government's positive outlook on biotechnology, the appointment of a new FDA chief for biologics, and an increase in the number of FDA examiners for biopharmaceuticals, all of which are expected to help move products through to commercialization at a faster rate.

Despite the plunge in stock values and the pessimistic outlook toward recovery, many companies have gone ahead with public offerings of stock. According to a recent report in *Bio/Technology* [**10**, 481 (1992)], 37 companies raised $1.3 billion in the first quarter of 1992 with public offerings. However, the amount of money raised tapered off dramatically throughout the quarter. ☐

Biotech stock prices fall from all-time high

Company	May 1992			52 weeks[a]	
	High	Low	Close	High	Low
BIOPHARMACEUTICAL					
Affymax	$21¼	$17¼	$20	$41¾	$15
Agouron Pharmaceuticals	13¼	11⅜	12¼	24	10¾
Alkermes	14	10	10¼	28¾	8½
Amgen	61	53⅛	61	78¼	35⅜
Applied Bioscience	18⅝	13⅝	13⅞	20⅛	12⅝
Athena Neuroscience	9¾	7¾	8½	18½	7½
Biogen	25¾	21½	25¾	49	18¼
BioTechnology General	8	6½	7⅜	11¾	3½
Cambridge Bioscience	9⅛	7¾	7⅞	12⅝	4⅞
Cambridge Neuroscience	7¾	6	6	14¾	4¾
Centocor	12¾	10½	12	60¼	9¾
Cephalon	12¼	8¾	9	19½	8¼
Chiron	55	41¾	55	79	34¾
Cor Therapeutics	11⅝	10½	11¼	22	7½
Curative Technologies	13⅝	7½	7½	23	7¾
Cytel	12½	8¾	9¼	22½	7¾
Cytogen	19¼	15	18½	34¼	12¼
Genelabs Technologies	7	5½	5⅝	13⅛	5½
Genentech	29	26¼	29	36¼	24⅜
Genetics Institute	29⅝	28	29¼	33	25
Gensia Pharmaceuticals	38⅝	29¾	38⅝	46¾	12¾
Genta	9	7¼	8	18¼	6
Genzyme	51	42¾	51	66½	29½
Gilead Sciences	14½	11	12¼	24¼	10⅜
Glycomed	13¾	10	11	25	5½
Icos	9⅛	7½	8½	21½	6½
ImClone	13¼	9½	13¼	28	8
ImmuLogic	12½	9⅞	10¾	25	8¾
Immune Response	22¾	17¾	22¾	62¾	9½
Immunex	31¼	26¼	31¼	68	22½
Immunomedics	9¾	7	8½	17	6⅛
Isis Pharmaceuticals	10½	8¾	9¾	21½	8½
MedImmune	29¼	18½	18¾	55	10¼
NeoRx	4	3 11/32	3 13/16	6 7/16	⅞
Nova Pharmaceutical	5⅞	4⅛	5¼	10⅝	3⅞
Regeneron	14¼	11⅛	13¾	23¼	9¾
Repligen	13¾	11¼	12	30¼	9½
Scios	14¼	10⅝	14	26⅜	10¼
Synergen	47¼	38	47¼	75	21⅛
SyStemix	30¾	25	26	60½	19
Xoma	22¼	15½	20¼	31½	12¾
AGRICULTURAL					
Biosys	11¾	9⅞	10½	14¼	9½
Calgene	15⅜	11⅝	14¾	16	6½
Crop Genetics	7	5⅜	6½	12¾	3
DNA Plant Technology	7	5⅜	6¾	9⅛	3¼
Ecogen	9⅞	8½	9	14½	7
EcoScience	8¾	6¼	7½	12½	5¾
ESCAgenetics	10½	8¾	8¾	14⅛	5
Mycogen	15	13⅝	14½	19¼	11¼

[a] The 52 weeks preceding the last week of May 1992.

CHEMICAL & ENGINEERING NEWS

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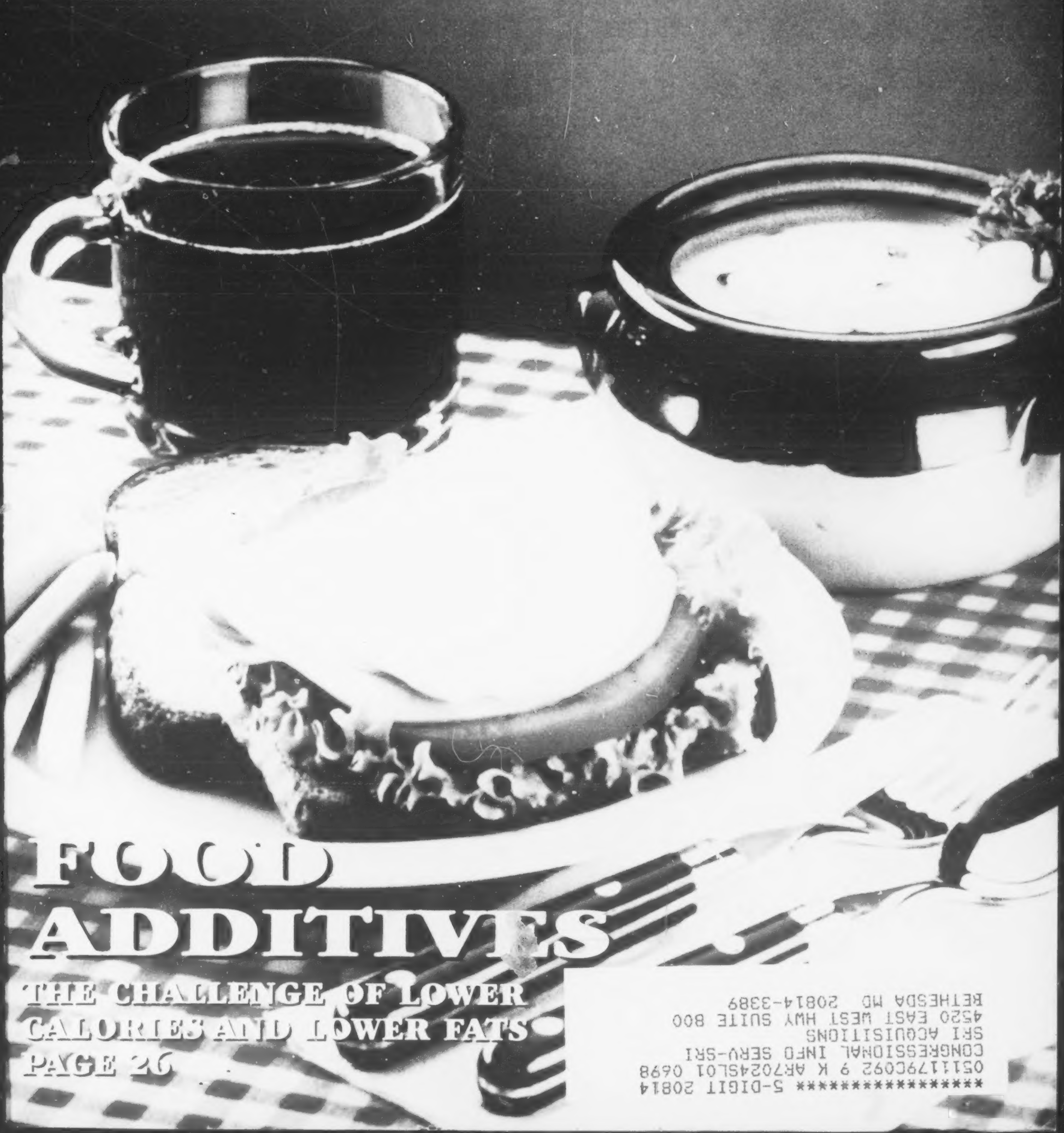
POLYPROPYLENE DEMAND, BOOSTED BY EXPORTS, BEGINS TO RECOVER PAGE 9



FOOD ADDITIVES

THE CHALLENGE OF LOWER CALORIES AND LOWER FATS

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C&EN

JUNE 15, 1992

NEWS OF THE WEEK

- Delegates at UN-sponsored Earth Summit reach consensus on several tough issues, but U.S. chooses not to join pacts on biodiversity, carbon dioxide emissions levels, other issues. Page 4
- FDA adopts policy that would allow continued development of chiral drugs, pleasing industry. Page 5
- W. R. Grace completes several business deals, including the sale of its Massachusetts-based organic chemicals division. Page 5
- NSF says Pentagon is blocking transfer of funds, thus delaying startup of Critical Technologies Institute. Page 6
- Robert J. Massie, 43-year-old former president and chief executive officer of reference publisher Gale Research, is named director of Chemical Abstracts Service. Page 6

COVER: Photo courtesy of FMC

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CENEAR 70 (24) 1–56
ISSN 0009-2347

BUSINESS

U.S. producers of polypropylene raise prices and plan capacity expansions as market strengthens, but may face cuts in exports as capacity in Latin America and the Far East grows. **Page 9**

GOVERNMENT

Toxics Release Inventory data supplied by U.S. industrial facilities to EPA show a 26% drop in emissions of toxic chemicals between 1987 and 1990. **Page 13**

Superfund's controversial liability system and options for its change when the law is renewed next year are the topic of an analysis by Resources for the Future. **Page 14**

Japanese Cabinet issues science and technology policy guidelines for the next 10 years, reflecting concern that Japan is losing prowess in technical areas. **Page 16**

SCIENCE/TECHNOLOGY

Noted U.S. scientists urge release of imprisoned Chinese colleagues in letter to Chinese Premier Li Peng, marking third anniversary of Tiananmen Square political crackdown. **Page 20**

NASA's recently launched Extreme Ultraviolet Explorer satellite will be the first to make both spectroscopic and wide-band observations over the entire extreme UV region. **Page 20**

PRODUCT REPORT

Food additives, particularly fat substitutes and nonnutritive sweeteners, are a booming industry as a result of consumer demand for low-fat, low-calorie versions of long-enjoyed foods. Page 26

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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Environmental science course

I am pleased to read that Princeton University faculty is developing a new course in environmental sciences for nonscience majors with emphasis on chemical principles (C&EN, May 18, page 24).

I authored an outline for a similar course ["Introduction to Environmental Sciences: a Course for Nonscience Majors," *J. Environ. Sci.*, **15**(4), 27 (1982)]. The concept didn't become popular at that time, perhaps because no Ivy League campus was involved or no National Science Foundation megabucks were spent. Nevertheless, it gives me great satisfaction to see some progress in this direction. A vast majority of college students need to learn basic chemical concepts related to environmental issues for their personal and societal improvement.

Gian Gupta
University of Maryland, Eastern Shore

Global warming

You state on the Editor's Page (C&EN, April 27, page 3), "Despite the complexities and uncertainties [of global warming], there are three essentially undisputed facts. . . . The bulk of this 27% carbon dioxide increase has been due to human activity, mainly the burning of fossil fuels."

I would like to inform you that I, for one, cannot accept this statement as undisputed fact. According to my calculations—for which I use internationally recognized, country-by-country consumption data reported for natural gas, coal, and oil in 1988—global fossil fuel consumption is responsible for only up to about 3% of total annual carbon dioxide emissions. The bulk of carbon dioxide emissions is from respiration by biomass and soils and oceanic emissions. The decrease in carbon dioxide sink capacity through such mechanisms as deforestation also plays an important role in carbon dioxide buildup. So unless there is a very efficient separation scheme in operation that selectively removes non-fossil-derived carbon dioxide emissions from the atmosphere, your statement should not be called an undisputed fact.

Based on current technology, the most practical way to reduce ambient carbon dioxide is to grow more biomass, since it fixes considerably more carbon via photosynthesis than it respires. And consumption of biofuels derived from biomass also adds no new carbon dioxide to the environment because of the relatively short recycling time of biomass carbon. Reduction of fossil fuel consumption, especially coal and oil, by increased use of biofuels can reduce atmospheric sulfur oxides, nitrogen oxides, ozone, and unburned reactive hydrocarbons, all of which contribute to subquality air. But elimination of, or a major reduction in, fossil fuel use might be expected to have a small impact on atmospheric carbon dioxide buildup.

Donald L. Klass
President, Biomass Energy Research Association, Washington, D.C.

Computers in chemistry

Can drugs be designed by computers that characterize all molecules as though they existed as gases in a vacuum? When a process as fundamental as absorption of one dioxygen molecule by hemoglobin involves 80 water molecules [*Science*, **256,** 618; 655 (1992)], what can we learn about docking a drug in vacuo? Though the free energy change per water molecule fixed may be small, the involvement of a lot of them can significantly alter geometry and the point of equilibrium.

Not only is there a lot of enthalpy involved in any hydration process, there is also a major entropic change owing to the ordering of what were randomly distributed small molecules. When that large entropy change is manifest in the transition state, it implies existence of a large enthalpy of activation, which, in turn, causes rate to be unusually sensitive to changes in temperature. A similar argument explains why bioequilibria are so often unusually temperature sensitive.

Add to these complications the fact that solvation not only influences targeting a disease area but also affects routes to side effects, and we appreciate that the computer is not about to replace the skilled chemist. (True, a Cray or equivalent supercomputer can surround a molecule with water—given enough time.)

Perhaps all this explains why in six pages on uses of computers in chemistry (C&EN, May 11, page 40) I didn't find mention of any actual contribution to the solution of a commercially significant problem.

Benjamin J. Luberoff
Summit, N.J.

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Market for Polypropylene Is Strengthening as Economy Improves

■ ***U.S. producers raise prices, consider capacity increases, but may face future cuts in exports as foreign capacity grows***

Susan J. Ainsworth, C&EN Houston

After weathering the storms created by the Persian Gulf War and the persistent recession, business is looking a bit brighter for U.S. producers of polypropylene. Demand for the product is strengthening as the economy begins a recovery. In addition, exports, which reached record levels last year, remain strong.

In response, sanguine producers have taken another stab, after the recent unsuccessful attempt late last year, at a polypropylene price increase, hopeful that it will stick. They have also started to think about building the next wave of capacity. Just last month, Phillips Petroleum teamed up with Sumika Polymers America, a subsidiary of Japan's Sumitomo Chemical, to study whether the two will jointly build a 270 million-lb-per-year polypropylene plant at Phillips' chemical complex at Pasadena, Tex., near Houston (C&EN, June 1, page 6).

But some consultants are cautioning that a cloud may soon loom over the U.S. polypropylene market. Capacity is going up all over the world, especially in Latin America and the Far East, and these historical polypropylene importing countries are poised to become exporters. As a result, U.S. exports may sag as these new plants come on stream over the next year or two. That could spark an eventual reversal of any polypropylene price increase producers may get now.

Nevertheless, "virtually every domestic producer is pushing for a 3-cent-per-lb price increase now," says Mark House, vice president for polymers at Houston-based consultants DeWitt & Co. Producers were roughly evenly split on when their increases were to become effective—half had set a June 1 date and the other half had set May 15. Current pricing for injection-grade homopolymer polypropylene is 31 to 33 cents per lb for buyers protected until July 1.

It's too early to tell whether this latest attempt at a polypropylene price increase will be successful. "The vast majority of volume users get 30-day protection, so we won't know how the increase will stick until sometime late in June or into July," House points out. Seven to 10 days after the implementation dates for the new prices, the large-volume users always shop around for deals. The kind of deals they get will depend on how badly some producers want higher prices; some may settle for the additional market share they might get by giving a lowball price, House says.

Still, House gives the increase a reasonable chance of success. He points out that polypropylene operating rates in the U.S. were a healthy 91% in March of this year, based on the latest statistics released by the Society of the Plastics Industry. If those rates hold, he reasons, producers will have more options available and will be more likely to put business at risk to implement an increase. "Demand has been strong and I don't see why it won't continue to be as strong as it has been," House says.

Indeed, demand for polypropylene looks to be healthy now and into the future. Chemical consulting firm Chem System's May 1992 report on polypropylene shows U.S. demand for this polymer will grow from 6.39 billion lb in

Polypropylene demand to be strong through 2000

Billions of lb	1990	2000	% annual growth rate
U.S.	6.39	11.5	5.8%
Western Europe	8.16	17.0	7.6
Japan	4.0	6.0	4.0

Source: Chem Systems

POLYPROPYLENE
PLANT

Phillips 66 plant in Pasadena, Tex., has capacity of 480 million lb of both homopolymer and random copolymer resin grades for injection molding, sheet, other markets

1990 to 11.5 billion lb in 2000, posting an annual growth rate of 5.8%. It predicts polypropylene demand in Western Europe will grow even faster, at 7.6% annually. In Japan, the annual growth rate for polypropylene is likely to be 4.0%.

"Demand is up sharply, and we expect that trend to continue as the economy continues to strengthen," says Kenneth F. Dowd, vice president for sales and marketing at Himont, which announced price increases of 3 cents per lb on some of its polypropylene grades, effective June 1. DeWitt's House points out, "There's been a hiccup in housing starts, retail purchases are up, sales of consumer durables have risen, and the packaging market is extremely strong." The only segment that is still lagging significantly is the automotive market, House adds, and only companies heavily into automotive-grade polypropylene are suffering from weak sales and low operating rates now.

Another reason consumption is rising is that buyers are restocking to keep up with the current level of business after starting the year with "lower, cautious inventories," says House.

In addition, the export market continues to soak up excess capacity, thus polypropylene plants can keep running at high capacity. In fact, the U.S. polypropylene market reached a record export level of 2 billion lb in 1991, says House. Polypropylene is still being exported at about 75% of last year's rate, he adds.

Although exports are eating up excess U.S. production and boosting overall polypropylene sales, there's a down side to the boom in exports. Exported product margins are substantially lower than domestic margins, notes Michael Horvath Jr., a petrochemical consultant with Petrocon Associates in Houston. That's especially true for product going into such markets as China and Taiwan, he says. "These markets simply won't pay what the U.S. market is paying for polypropylene homopolymer and some of the higher performance grades. Exports are selling for 5 or more cents per lb less." Despite the high level of exports, companies are not going to see a proportionate jump in polypropylene profits.

Still, the strong demand and export situation is good news for producers, especially Amoco Chemical and Formosa Plastics—two companies that plan to start up additional polypropylene capacity in Texas before the end of this year.

An Amoco spokesman says the company plans to complete its new polypropylene unit at Chocolate Bayou, Tex., "sometime this summer." The unit, based on Amoco's proprietary gas-phase process and high-yield catalyst, will add 300 million-lb-per-year capacity and position the company as a contender in international licensing.

Spate of firms compete for polypropylene market in U.S.

	Annual capacity (millions of lb)
Amoco Chemical	
Alvin, Tex.	1,120[a]
Cedar Bayou, Tex.	550
Aristech Chemical	
Kenova, W.Va.	330
La Porte, Tex.	390
Eastman Chemical	
Longview, Tex.	540
Epsilon Products	
Marcus Hook, Pa.	260
Exxon Chemical	
Baytown, Tex.	1070
Fina Oil & Chemical	
La Porte, Tex.	900
Formosa Plastics	
Point Comfort, Tex.	165[b]
Genesis Polymers	
Marysville, Mich.	140
Himont	
Bayport, Tex.	1,050
Lake Charles, La.	1,075[c]
Huntsman Polypropylene	
Woodbury, N.J.	360
Lyondell Petrochemical	
Bayport, Tex.	300
Phillips 66	
Pasadena, Tex.	480
Quantum Chemical	
Morris, Ill.	300
Rexene Products	
Odessa, Tex.	180
Shell Chemical	
Norco, La.	340
Seadrift, Tex.	200[d]
Solvay Polymers	
Deer Park, Tex.	450
TOTAL	**10,200**

a Three hundred million lb of this capacity expected on stream sometime this summer. **b** Expected to be on stream by the end of 1992. **c** A portion of this capacity is a joint venture between Himont and China's Impel. **d** Plant is a joint venture between Shell and Union Carbide Chemicals and Plastics Co. **Source:** SRI International Directory of Chemical Producers, company data

Meanwhile, Formosa Plastics is expected to bring on a 165 million-lb-per-year line of polypropylene at its Point Comfort, Tex., site, by year's end and add two more lines of equal size sometime in early 1993, for a total annual capacity of 495 million lb.

These U.S. expansions are minimal compared with what is going on in other parts of the world, particularly the Far East and Latin America. "The Koreans built a slew of capacity and have flooded the Far East with polypropylene," notes House. In addition, between 1992 and 1993, 15 new plants will go up in that region, adding a total capacity of 2.88 billion lb per year.

Expansions are taking place elsewhere, too. Most recently, Himont and a leading Mexican industrial corporation, Grupo Industrial Alfa, jointly inaugurated their $128 million polypropylene production facility at Altamira, Tamaulipas, Mexico, which will have the capacity to produce 330 million lb per year of polypropylene.

"There are low market entry barriers into the polypropylene business [because] technology licensers are abundant and it is not a high-cost technology relative to other petrochemicals in the production chain," says Don F. Bari, manager of polymer technology at Chem Systems and an author of the firm's polypropylene study. "However, long-term success is very dependent on several factors such as technology selection, market focus, feedstock position, global participation, and R&D effort."

All this new global capacity is becoming a storm cloud that threatens to rain on U.S. producers' polypropylene export parade. The Far East and Latin America are now building plants and becoming exporters, Bari adds. Because of this global capacity buildup, exports from the U.S. are expected to decrease significantly.

Although many seem to agree that U.S. polypropylene exports will drop, no one is quite sure when it will happen. Certainly, it will depend in part on the health of the Far East economies. "We originally thought exports would drop off early this year, but now we think that may not happen until the end of 1992 or the beginning of 1993," because of some delays in Far East polypropylene plant startups, Bari says.

Phillips 66 worker examines test strips of various grades of polypropylene

Under this scenario, the Chem Systems study forecasts that operating rates at U.S. polypropylene plants will decrease to about 80% until at least 1994. In addition, if producers do get all or part of the 3-cent-per-lb polypropylene price increase now, "we may see a reversal of this price trend when new capacity comes on," says Bari.

At least one other consultant believes the new capacity in the Far East and Latin America may not affect the U.S. market as quickly as some fear. Although many countries are building polypropylene capacity to supply demand in their own backyards, the U.S. will still be in a favorable position to supply those markets, says Horvath.

The U.S. has an advantage over many of these nations because of lower costs and better availability of propylene feedstocks. In contrast, many of the new producers outside the U.S. must rely on costly imported feedstocks. As world crude oil prices rise, these countries, especially those that have mostly naphtha-based producers, become less competitive. So even though alternative propylene values may rise in the U.S. (propylene is used to make alkylate for gasoline), the abundance of U.S. propylene will still keep propylene prices relatively low so U.S. polypropylene producers maintain an edge, Horvath says.

"As long as the 'gas bubble' in the U.S. keeps natural gas and natural gas liquids prices low, the U.S. will enjoy a structural advantage over producers in many countries." This factor, he explains, is big enough to offset the cost of transporting resin from the U.S. even though U.S. producers must settle for lower polypropylene prices.

These local producers that must import naphtha feedstock at current market prices and crack it to make propylene will still have significant market share, says Horvath. Despite being higher-cost producers, they will supply their basic local market. Lower cost imports, as from the U.S., will supply the remainder of the market and will likely supply any short-term growth in that market.

Horvath agrees that production outside the U.S. will erode the U.S. export market, but believes it will happen further down the road, beyond 1994. It will depend, he adds, on when the gas bubble disappears, on the growth of U.S. imports of natural gas liquids for ethylene feedstocks, and on the impact of possible foreign government subsidies or import duties that may improve the cost position of local plants.

Even as the U.S. polypropylene industry frets over capacity expansions outside the U.S., producers continue to look ahead to determine when robust demand for their product might outstrip even this new wave of supply. "If you project the growth rate out, we will run out of polypropylene capacity in the 1995–97 time frame," House forecasts. So far, the Phillips-Sumika venture is the only one to announce it is studying whether to build new U.S. capacity to meet demand in 1995. House expects that the venture will not be alone in adding capacity during 1995–97. "We will see a rash of producers planning to build polypropylene capacity. A number of them are studying the situation now."

Because polypropylene demand is growing faster than any of the thermoplastics', House expects to see an expansion in polypropylene ahead of expansions for other plastics. "There's got to be more capacity out there eventually. And the last thing a cagey producer wants to do is be the last to add capacity." ☐

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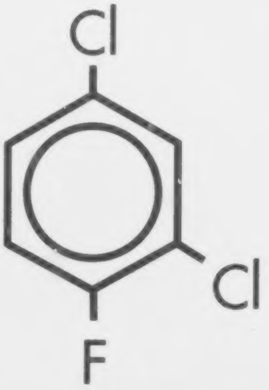

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PRODUCT REPORT

FOOD ADDITIVES

Ann M. Thayer,
C&EN Northeast News Bureau

Concern over health and nutrition is increasing the public's appetite for low-fat and low-calorie foods. But rather than altering their diets to include foods naturally low in fats or sugar, many people want to continue enjoying the same foods they have always eaten.

According to a survey from the Calorie Control Council, an Atlanta-based trade association, about 75% of the U.S. adult population consumes low-calorie or low-fat foods, and two thirds of those surveyed would like to see the number of available products increase. Such consumer demand is driving food producers to offer new fat replacers and high-intensity sweeteners for entirely reformulated reduced-fat and low-calorie versions of foods.

These influences have made calorie reduction agents the single largest segment of the $3.8 billion market for food additives—accounting for 30% of the total, or $1.17 billion in 1991. This segment is expected to remain the largest through 1996, according to a Pathfinder report from Technomic Publishing Co.'s Business Research Group, Lancaster, Pa. However, the estimated annual 2.1% growth rate belies the activity this market will undergo. In fact, fat substitutes and nonnutritive sweeteners are among the most dynamic of food additive markets.

The calorie reduction industry has been dominated by the billion-dollar artificial sweeteners market, which will drop in value as competition increases. However, the still-new market for fat replacers is expected to grow rapidly over the next several years, and competition will heat up as more and more companies develop products. Obviously, companies would like to be positioned with the ideal combination of a successful sweetener and a successful fat replacer, says J. Charles Forman, an analyst for the Pathfinder report.

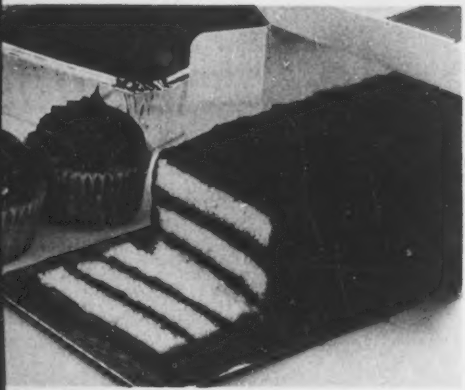
All major food categories and markets offer possibilities for the developers of low-calorie and low-fat food additives, but predicting the direction of these markets is very difficult. Many products face costly, lengthy, and uncertain regulatory approval processes. The Calorie Control Council, for instance, says half of the food additive petitions now being considered for approval by the Food & Drug Administration apply to low-calorie and "light" products. If approved, not only would the number of available products expand, but so, too, would the food categories in which they may be used. For fat replacers, technical hurdles stand in the way of developing effective products and, ultimately, products whose use in new food formulations consumers will accept.

Fat replacers growing market

Fat reduction has captured the interest of the public, and therefore the attention of the food processing industry. Several companies are investing in development of fat replacers, and many already have responded with new products. Although fat replacers had a market value of only about $100 million in 1991, according to the Pathfinder report, it is expected to grow 25% per year and thus triple by 1996. The estimated market for reduced-fat food products is already nearly $30 billion.

Estimates by companies indicate individual products are expected to have annual sales between $50 million and $100 million. This is especially attractive because many fat replacers currently on the market are older materials—starches, gums, and celluloses traditionally used as thickeners and emulsifiers—"dressed up in new clothes" for the fat replacement market. Newer materials are protein-based fat replacers and synthetic or alternative fats.

"There is room for a number of these



National Starch & Chemical photos

products because there are so many different kinds of foods and food formulations," says Forman. Many fat replacers now are used in cheeses, frozen desserts, salad dressings, and mayonnaise-type products. "I question whether there is going to be room for a number of them to really score and become 'megaproducts,' " he adds. Despite consumer surveys indicating a desire for low-fat foods, taste, price, variety, and ease of preparation rank higher than nutritional value among consumer responses.

Lyn Nabors, associate director of the Calorie Control Council, says: "The catch is that people want these products to taste like the regular products. You can get consumers to buy a product once, but if it doesn't taste good, they are not going to buy it again." Many in the industry suggest that there has been a rush to the market with poor-tasting products that can hurt the long-term potential for fat replacers. However, Nabors believes the industry has made strides in the past year or so. "There are more ingredients available and the companies making these low-fat ingredients are providing their customers with some technical expertise by telling them how to use them."

The competitive future of such products will depend on how easy they are for food processors to use, how successfully they behave like fat, and whether products can be reformulated to have the same taste and texture as full-fat versions so as to meet public acceptance. The idea of a miracle ingredient with sales of $500 million or more is not realistic, says Karen Penichter, food market development manager at Chicago-based FMC. "To think that one substance will do everything is a real stretch of technology." There are many different types of fat from a variety of sources, she explains, and each functions differently in a wide range of applications.

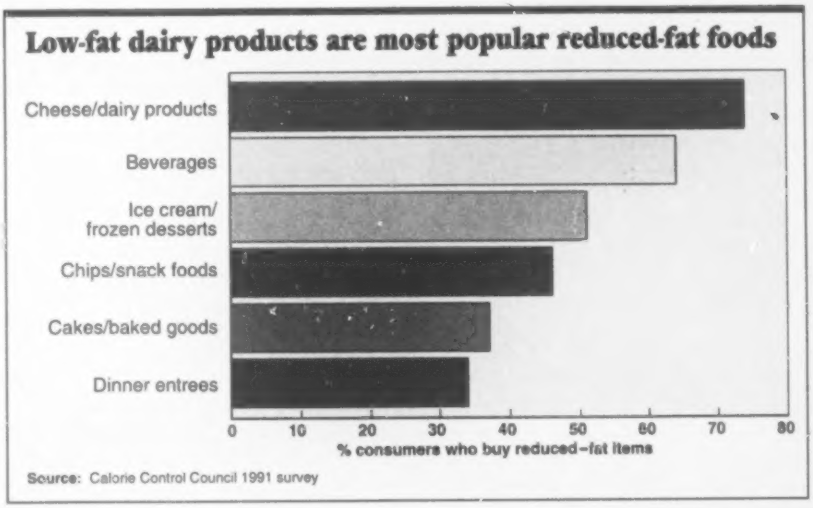
"To replace all the attributes of fat is very complicated," Penichter says. Fat has physical properties such as texture, lubricity, viscosity, and structural stability that contribute to its role in foods, as well as its appearance, flavor, and reactivity. "There has been a first wave of reduced-fat and low-fat products, and we have [captured] some of the basics, but consumers and food processors are saying, 'Give me more, give me better.' "

Carbohydrates replace fats

Carbohydrates have provided many early entries into the fat replacer market. Unlike fats with 9 calories per g, carbohydrates such as starches or dextrins (low molecular weight polysaccharides from the partial hydrolysis of starch) contribute 4 cal per g when metabolized. Cellulose, a polysaccharide differing from starch in the configuration of its glycoside linkages, contributes no calories when used as a fat replacer because it is not metabolized by the body.

Starches (a mixture of amylose and amylopectin) can mimic the bulk and texture of fat when mixed with water to form bland gels. The level of starch in fat replacement formulations typically is up to about 25 to 30% of the formulation, depending on the desired gel consistency. Depending on the level of solids, carbohydrate-water mixtures can have properties ranging from oil-like to lardlike. Because water is a major component of this mixture, the number of calories is reduced to 1 cal per g or less. Such mixtures often can replace up to 100% of the fat in many foods, but cannot be used for frying—a major source of fat in people's diets.

Carbohydrate-based fat replacers generally are sold as powders, which have much longer shelf lives and avoid the added costs of shipping premixed gels. Food processors must mix the powders with water, either before or after mixing with other ingredients.


Low-fat dairy products are most popular reduced-fat foods

Source: Calorie Control Council 1991 survey

When heated, stirred, and cooled, these fat replacers form a fatlike material. Because modified food starches have long been recognized as safe to consume, many starch-based fat replacers have shown up on FDA's GRAS list (generally recognized as safe) and have entered markets easily.

In January, National Starch & Chemical launched a line of fat replacers called N-Lite, designed to replace fats in a variety of foods applications. Doubting the utility of a "magic bullet" approach, the company worked with corn and other starches to develop what it calls a "systems approach" to fat replacement. This approach differentiates its products from those of other firms, says the company, because it recognizes the properties and roles of different fats in foods and then tailors the starch to have the organoleptic and functional properties needed for specific applications.

"The challenge is to make starch, a hydrophilic polymer, behave as fat, a hydrophobic monomer," says Peter Trzasko, a research associate at National Starch. Fat is not a single compound, but rather a family of triacylglycerols, which consist of three fatty acids, saturated or unsaturated chains generally composed of between eight and 18 carbons, esterified to a glycerol backbone. Depending on the combination of chain lengths and the degree of unsaturation, fats will have very different physical properties, and, therefore, different uses.

The associations between starch molecules can be controlled to mimic fat's properties, explains Trzasko, depending on the starch's chemical structure and how it is physically processed. Conventional methods of starch modification result in the random generation of molecules with wide distributions of sizes and shapes. By selecting the source of the starch and using proprietary, novel enzymatic or chemical hydrolytic procedures, National Starch controls the modification process.

N-Lite B, for example, is a specialty maltodextrin for use in baked goods. Reduced-fat baked goods, considered by many to be a major challenge, must retain moisture and a doughlike or cakelike structure. For frostings and fillings, N-Lite F, a mixture of modified food starch, nonfat dry milk, emulsifiers, and guar gum is used. The starch and gum give the mixture the body and feel of fat, whereas the dry milk acts as a stabilizer, and a polyglycerol ester emulsifier traps air during whipping.

N-Lite D is a modified food starch for use in dairy foods. Formulated for liquids for uses other than frying, N-Lite L and N-Lite LP are oily, viscosity stable, and stable to any heat and shear that might occur in food processing. N-Lite L is designed for systems requiring cooking, such as sauces and puddings, where high enough temperatures are reached to cause its modified starch to gel. N-Lite LP is pregelled for instant-food applications.

National Starch also has developed two products derived from tapioca. N-Oil is a maltodextrin for salad dressings and dairy-type products. Slenderlean, a modified starch, can be used at levels of only 1% by weight to reduce the fat in sausages to less than 10% by weight.

Other starch-based or maltodextrin-based fat replacers are sold by Grain Processing Corp., American Maize Products, Remy, Avebe, and A. E. Staley. Staley, the Decatur, Ill., affiliate of England's Tate & Lyle, produces Sta-Slim, made from modified potato and tapioca starches. Grain Processing Corp., of Muscatine, Iowa, produces a cornstarch maltodextrin product called Maltrin, and Dutch company Avebe makes Paselli-SA2, a potato starch maltodextrin.

Rhône-Poulenc's U.S. arm in Cranbury, N.J., has teamed up with Quaker Oats to develop and market Oatrim. Licensed from the Department of Agriculture to the two companies and to ConAgra of Omaha, Oatrim is produced by the enzymatic treatment of oat flour and oat bran. Its high β-glucan content, says Richard V. Kennedy, senior vice president and general manager of Rhône-Poulenc's food ingredients unit, gives a creamier taste and texture than other fat replacers. Rhône-Poulenc will have marketing and sales responsibilities for Oatrim food ingredient products made from materials supplied by Quaker Oats.

A year ago, Staley introduced Stellar, an acid-modified cornstarch, as a fat replacer for a variety of food applications. Unlike cellulose particles and some starches that undergo syneresis—losing water and thickening over time—Stellar retains water and its fatlike qualities, making it useful in low-moisture reduced-fat foods, says Sylvia Wulf, marketing manager for new products at Staley. Moderate heat processing is possible, up to about 70 °C, but Stellar can't undergo the retort or aseptic processing used in canned foods. Its stability to heating, freezing, and thawing also depends on the presence of other ingredients. By lowering the pH and adding a preservative to avoid microbial growth, the material can be stored for a few weeks under refrigeration.

Stellar is made by a process that modifies largely insoluble starch granules by depolymerizing the amorphous amylopectin portion to yield fragments with an average molecular weight about one tenth that of potato maltodextrin or tapioca dextrin. Under high shear or pressure (8000 psi or more), the particles adsorb water and immedi-

CIRCLE 2 ON READER SERVICE CARD →

ately form a particle gel (versus a typical starch polymer gel) that is similar to shortening. The gel consists of 2.5- to 15-µm aggregates of submicrometer starch particles, explains Wulf, and it is these soft, deformable particles that make Stellar behave as fat globules. The company provides samples of the gel or "crème" for evaluation and technical support services for the shearing process.

Stellar is more expensive than other starches, says Wulf, but less expensive than microcrystalline cellulose and much less expensive than NutraSweet's protein-based fat replacer, Simplesse. Most companies are reluctant to give figures for the price of their products, but industry estimates place Stellar at about $2.50 per lb. However, a more important competitive measure for fat replacers will be their cost versus use levels. According to the Pathfinder report, the cheaper carbohydrate-based products, if they work as well as claimed, will take over the fat replacer market. But it is likely no one product will dominate because the needs are very different in different foods.

Carbohydrate gums and hydrocolloids have been used for many years as thickeners, stabilizers, or emulsifiers in foods. Common hydrocolloids that are fermentation products, or seeds, plant exudates, and plant extracts—xanthan gum, guar gum, locust bean gum, gum arabic, pectin, and carrageenan—are very effective in their ability to "structure" water. As fat replacers, they can be used in very small amounts and essentially are noncaloric. Gums and hydrocolloids average a few dollars per pound, depending on how exotic their source.

Hydrocolloids may be used alone or in combination with other gums or fat substitutes to replace fat. When fat is removed from a product and replaced with a mimetic and water, a hydrocolloid is frequently added to develop texture, viscosity, or stability.

Fat replacers to show largest growth

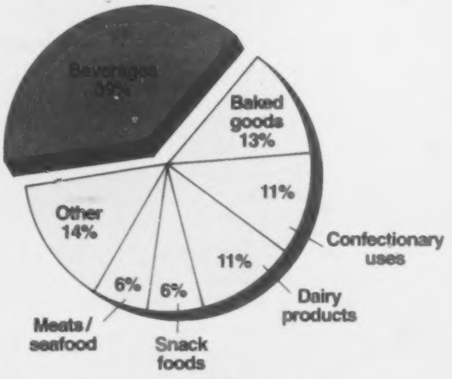
	Sales ($ millions)			% annual growth
	1986	1991	1996	1991–96
Fat replacers	$ 50	$100	$ 305	25.0%
Nonnutritive sweeteners				
Tabletop uses	175	220	316	7.5
Other applications	750	850	675	–4.5
Formulation aids[a]	850	920[b]	1084	3.3
Flavors & enhancers	575	675	911	6.2

[a] Includes emulsifiers, surfactants, thickeners, stabilizers, binders, and fillers. [b] Includes hydrocolloid gums at $270 million, cellulose and derivatives at $200 million. **Source:** Technomic Publishing's Pathfinder report

Among suppliers of these substances, Rhône-Poulenc has sold gum and hydrocolloids to the food industry for more than 40 years and has been expanding its business through acquisitions. Dow Chemical is a major producer of methylcellulose food gums, part of a major class of synthetic gums. Hercules produces carrageenan, extracted from seaweed, and a variety of gums, especially pectins. Pectins have been used for years in the food industry to thicken or gel aqueous systems such as jams or jellies.

In late 1991, Hercules introduced its Slendid product as a fat replacer. Slendid is a specialty pectin, or partial methyl ester of polygalacturonic acid, extracted from citrus peel. To use Slendid as a fat replacer, it is mixed at a level of 5% or less with water and a source of calcium to make it gel. As the gel forms, it is exposed to moderate shear to break it up, explains Noo Mangat, director of new business development for Hercules' food ingredients group. The resulting material has the consistency of applesauce and can be used "as is" in food formulations. If Slendid is to be used in a smooth formulation, such as a salad dressing, it can be homogenized to become creamy.

Beverage industry uses most food additives



1991 food additive sales = $3.83 billion

Source: Technomic Publishing's Pathfinder report

The size of fat particles depends upon how they are processed, says Mangat, and by no means fall in a narrow size range. Slendid's advantage over other products is that it behaves as a fat, he adds, breaking up or mixing under normal processing. Its small, stable pieces of gel simulate the behavior of an emulsified fat and, being soft and deformable, give the gel a fatlike feel. Other features include a fatlike meltability and a heat stability that allows for sterilization or pasteurization cycles such as those used for canned cream soups.

In practice, even replacing up to 100% fat with Slendid, it would appear at a level of only about 1% by weight of the food product and contribute negligible calories. On a cost versus usage level, says the company, it rivals other fat replacers. A principal advantage of pectin, adds Mangat, is that it is an extremely consumer-friendly food additive, as is starch. Thus, he believes changes in FDA labeling regulations, which may cause consumers to look more closely at food labels, will be positive for Slendid. Although meeting GRAS standards, USDA has not approved Slendid's use in meat products.

Another major producer of hydrocolloids is FMC. Like Pfizer, Rhône-Poulenc, Monsanto, and Hercules with new products in the area of "light" food ingredients, FMC's formation of a new food ingredients division demonstrates its commitment to the fat-replacer market. The company has consolidated marketing, technical, and business operations for its carrageenan, microcrystalline cellulose, and konjac flour materials.

FMC is the world's leading producer of carrageenan, currently used by meat processors to formulate low-fat ground beef products. FMC's Nutricol konjac flour, derived from an Asian tuber, has

← CIRCLE 2 ON READER SERVICE CARD

C&EN staff photo

Table-top uses are growing market for nonnutritive sweeteners

a unique ability to replace fat in meat products, says Penichter. In combination with starch or xanthan gum, it forms a stiff, heat-stable gel that can be handled like meat trimmings and will not degrade during cooking. FMC is awaiting USDA approval for Nutricol's use in meat products.

FMC is now promoting its Avicel microcrystalline cellulose, long used in drug tablets, as a fat replacer in frozen desserts, salad dressings, and bakery products. Avicel, a purified form of natural cellulose, consists of particles about 0.2 µm in diameter that, when mixed with water, form a network with a texture similar to fat. FMC also produces other versions with larger diameters, 10 to 15 µm, or rounded particles, says Penichter. Since cellulose is not metabolized, Avicel acts as a nonnutritive fat replacer.

Pfizer reformulated its polydextrose bulking agent, long used to replace sugar, and began promoting it as a fat replacer called Litesse in early 1991. The company is investing "significant resources to expand its position as one of the world's leading suppliers of 'lite' food ingredient systems," says Donald F. Farley, executive vice president of the Pfizer Specialty Chemicals Group. In late 1990, Pfizer sold its citric acid business as part of its new strategic focus on "performance food ingredients and proprietary, customized food additive systems and applications technologies."

This month, the company announced it will make a second-generation version, Litesse II, available later this summer for customer scaleup and test marketing. The newer version, says the company, is improved measurably

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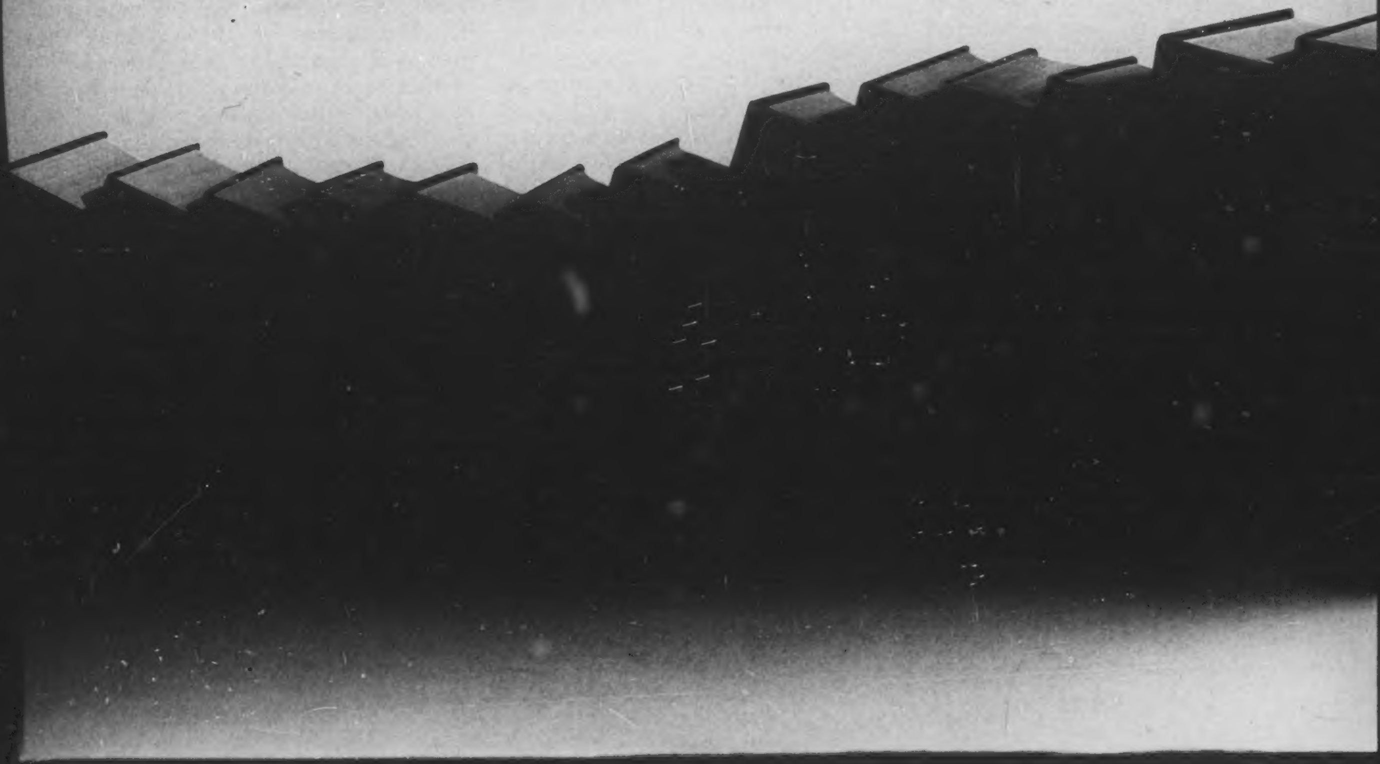


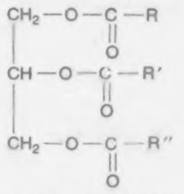
in taste quality so that it may be used in highly flavor-sensitive foods. At 1 cal per g, both Litesse versions can be used as bulking agents or to replace fat in baked goods, frozen desserts, yogurts, sauces, and spreads.

Proteins to form particulates

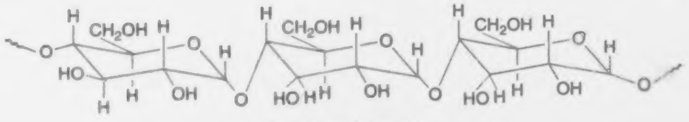
Protein-based fat replacers are designed to mimic the lubricity of fat through the use of small particles. With diameters of 0.1 to 3.0 μm, protein particles are perceived in the mouth as "creamy." Like carbohydrates, protein has 4 cal per g, and contributes fewer calories in fat replacement systems where the particles are mixed with water. Some protein-based fat replacers can be used in baked applications but, like several other fat replacers, cannot withstand the heat used in frying.

Simplesse, marketed by the Monsanto subsidiary NutraSweet—producer of the aspartame sweetener sold by that name—is the only protein-based fat replacer available in the U.S. Two versions are available, based on different

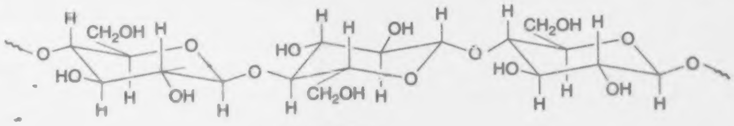
Polysaccharides' structure differs from fats' structure


R, R′, and R″ generally are saturated or unsaturated straight chains containing between eight and 18 carbon atoms

A triacylglycerol (fat)



Amylose (starch)



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materials—-one is microparticulated egg white and milk proteins, and the other is whey protein. The company's patented process combines high heat—above pasteurization temperatures—and high shear to form the proteins into spherical particles. Simplesse is sold either in a liquid form or as a powder, the latter offering economies of transportation and a significantly longer shelf life.

In early 1990, FDA categorized the egg- and milk-based Simplesse as GRAS for frozen desserts. This was after an aborted attempt to launch the product two years earlier when the company announced that its product did not require approval because it was made from GRAS materials. The lesson learned when FDA intervened, say industry observers, was that "GRAS plus GRAS does not equal GRAS." In 1991, the liquid or dry whey version was permitted for use in cheeses, salad dressings, and mayonnaise products. Applications are pending with FDA for further uses of the egg-milk version.

In 1990, NutraSweet launched Simplesse only in its own frozen dessert product, Simple Pleasures, putting itself in competition with its potential customers. The company is enthusiastic about its dessert products, which it says are in 85% of U.S. markets and are the top "unit" seller, but not necessarily top volume seller, among low-fat/fat-free frozen desserts. Despite this, many industry observers question the wisdom of NutraSweet's approach.

"Some new fat replacer products

Continued on page 36

Fat replacers integral to new food formulas

Fat replacers are being used as major ingredients in many salad dressings, mayonnaise, and dairy-type products. Most fat replacer systems can be combined with other dry ingredients and then mixed with water. Alternatively, they may be prepared first as a gel or crème under the necessary mixing or heating conditions, and then added to the food product. For example, Stellar, an acid-modified cornstarch, requires high shear to make its particles adsorb water and form a shorteninglike gel. Processing Stellar in standard equipment with other ingredients could follow the type of food formula given here.

7.5% Fat Cheese-Flavored Spread	% wt
Stellar fat replacer crème[a,b]	39.30%
Water	29.63
Cheese powder	22.50
Nonfat dry milk	5.82
Mira-thik 468 starch[b]	0.65
Instant Tender-Jel 419 starch[b]	0.52
Lactic acid, 88%	0.34
Flour salt	0.32
Citric acid, powdered	0.26
Dipotassium phosphate	0.20
Color, red #40, 0.01% solution[c]	0.16
Potassium sorbate	0.15
Color, yellow #08031, 5% solution[c]	0.15

a 27% modified food starch and water. b A. E. Staley products. c Warner Jenkinson products. **Source:** A. E. Staley

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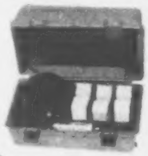

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Continued from page 32

have not been the barn burners they were supposed to be," says Forman. "NutraSweet and other firms have learned that low-fat dairy desserts do not have the consumer appeal of ice cream." Simplesse is a primary example, he adds. "[It] has not made the great market splash hoped, is considered a disappointment by many in the food industry, and has been written off by some analysts as a product with high cost and limited advantage." NutraSweet had projected sales of Simplesse products at about $450 million by 1992, he says. Yet Simple Pleasures' sales totaled only $12 million in 1990 and have not grown greatly since.

NutraSweet has gone on to market Simplesse as a food ingredient. It is used in 18 products worldwide appearing in several regional products in the U.S. The Simplesse logo is used on these products because, says a company spokesman, "consumers are a little bit confused by what's out there. . . . By putting the logo on products, it helps consumers because they know it's natural, it means good taste, and above all it means a reduction in fat."

Kraft developed a microparticulated protein-based fat replacer, Trailblazer, for in-company use—but ended up not using it after all. Instead, Kraft markets low-fat or fat-free products in 12 categories—more than any other company, it says. "During the time Kraft applied for GRAS approval [of Trailblazer], the company introduced all these other products using common natural ingredients that have been used for years and didn't require approval," says a company spokesman. "Kraft has been very satisfied with the quality."

Still under development is Lita, based on zein, a microparticulated protein from corn. Pfizer's specialty chemicals group has joined with Opta Food Ingredients of Cambridge, Mass., to develop the product. Like other protein-based fat replacers, it contributes less than 2 cal per g, has a bland taste, and can be produced in a liquid or powder form. The companies are said to be testing Lita in frozen dessert, whipped topping, and mayonnaise applications.

Alternative fats being developed

Several companies are developing synthetic fats or chemically altered fats, but to date none has been or is expected to be approved in the near future. In most cases, by altering the size, shape, or structure of fatlike molecules, the human body metabolizes these materials to a lesser extent, if at all. These are attracting attention both because of their synthetic nature and because they would be the first products to make inroads into frying applications. The best-known example is Olestra from Procter & Gamble.

Olestra is a sucrose polyester containing six to eight fatty acids esterified to sucrose, instead of glycerol. The fatty acids are derived from vegetable oils such as corn or soy. Being larger than a typical fat molecule, it is not hydrolyzed by digestive enzymes, not adsorbed, and passes through the digestive tract unchanged, says Procter &

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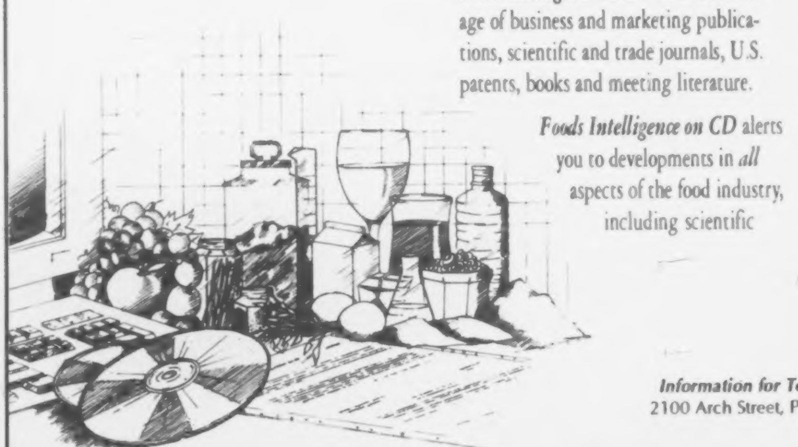

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Gamble. But, being chemically like a fat molecule, it is described as having physical properties, taste, and performance similar to a conventional fat. In practice, it could replace 100% of fat in fried foods and offer a corresponding reduction in calories.

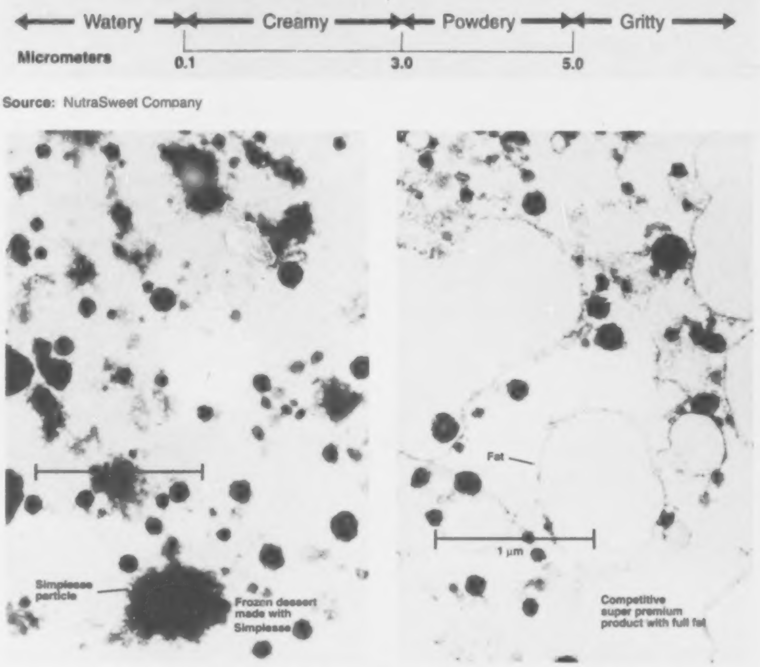
The company has been in discussions with FDA over Olestra since the early 1970s, spending millions of dollars and decades in developing and testing its product to meet safety standards. Since 1987, a 20,000-page petition that includes more than 100 animal studies and more than 25 clinical studies has been submitted to FDA for Olestra's approval as a food additive. In 1990, the company narrowed its petition to snack-food uses. Health issues, such as whether the product causes diarrhea or depletes the body of vitamins, have been raised but successfully answered, says the company.

Olestra's case is illustrative of more general issues. Among these is FDA's well-known caution in approving food additives. This is true especially for new materials with which it is unfamiliar and about which questions of inertness or innocuousness arise. Fat replacers pose questions about the quantity of additives in food because, unlike high-intensity sweeteners used in very small amounts, they might constitute a larger component of people's diets. Not only does the regulatory process become lengthy, say many in the industry, but when FDA does act, it often initially approves a product for very limited uses. Thus, older ingredients with a history of use and demonstrated safety either have not required, or have broader, approvals and have become more usable materials.

For example, in a 28-g serving of potato chips, Olestra would replace 100%, or 9.8 g, of fat from cooking and reduce the total calories 57%. Because of Olestra's long delay at FDA and because patents expire in 1994, Procter & Gamble has requested a patent extension from Congress. Although NutraSweet was granted an extension on aspartame for similar reasons, this action on Olestra has been widely criticized by several consumer groups. Only recently, Procter & Gamble disbanded its Olestra marketing effort.

Procter & Gamble also has developed caprenin, a reduced-calorie fat, with functional properties similar to cocoa butter. It differs from most fats in

Fatlike feel depends on particle size


Watery
Creamy
Powdery
Gritty
Micrometers
0.1
3.0
5.0
Simplesse particle
Frozen dessert made with Simplesse
Fat
1 µm
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Micrometer-size Simplesse particles (left) mimic "creamy" feel of butter fat in ice cream (right)

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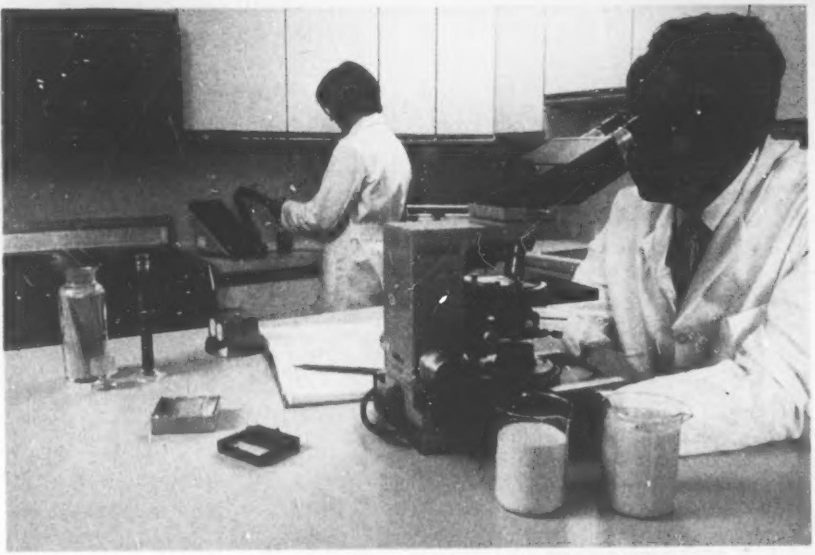
that two of its fatty acids are unsaturated medium-chain acids, caprylic (C_8) and capric (C_{10}), and the third is behenic acid (C_{22}). Caprylic and capric acids are obtained from coconut and palm kernel oils, whereas behenic acid is found in peanuts, some marine oils, and hydrogenated rapeseed oil. The combination of behenic acid, which is only partially absorbed by the body, and the medium-chain acids, which are metabolized like carbohydrates, yields a fat with 5 cal per g.

Caprenin is targeted at markets such as soft candies and confectionery coatings for fruits, nuts, and cookies, says the company, because it provides the rich, creamy, and chocolately taste of cocoa butter. Early this year, Procter & Gamble began selling caprenin, which is based on GRAS materials, to Mars for use in candy bars. Procter & Gamble has filed a petition with FDA to affirm caprenin's status as GRAS.


National Starch & Chemical photo

Technicians work with new additives in food formulations

Similarly, Arco Chemical, a subsidiary of Atlantic Richfield, is working on chemically modified fats. Its esterified propoxylated glycerols (EPGs) are naturally occurring fats with propylene glycol inserted between the glycerol and fatty-acid segments, explains Eileene Keating, EPG project manager at the company. "Because they are based on naturally occurring fats and oils, they tend to function as a fat or oil in food applications," she says. "However, because they consist of a larger molecule, the body doesn't recognize them as a fat or oil and essentially they are either not metabolized or metabolized to a far lesser degree [than a fat or oil]."

The properties of the material can be adjusted depending on the fatty-acid structure and the number of propylene glycol units inserted. "We have quite a few degrees of freedom in tailoring the EPG molecule," says Keating. "In today's industry, there currently are a number of fats and oils being used, each tailored to specific applications. No one fat or oil, be it a high-caloric or low-caloric one, is going to serve all needs." The company expects that several years will be needed to complete development, safety testing, and the regulatory approval process before commercialization.

"The products that currently are being used commercially as fat mimetics are based on carbohydrates or proteins," says Keating. "By their very nature, they cannot mimic all the different characteristics that a fat has in a food product." Like Olestra, Arco Chemical's patented EPGs could be used in frying or food formulations for reduced calories. "Olestra and EPG represent two products that have the potential of acting as true fat replacers in the literal sense."

A number of other alternative fat products are under development or are in use. For instance, one under development by Dallas-based Frito-Lay is dialkyl dihexadecylmalonate (DDM), a noncaloric fatty alcohol ester of malonic and alkylmalonic acids. Another one, previously under development by CPC

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Diet soft-drinks are major end-use market for nonnutritive sweeteners

International, Englewood Cliffs, N.J., is TATCA, or tricarballylic acid esterified with fatty alcohols, but that project has been put on hold.

Stepan, in Northfield, Ill., sells alternative fats for use in food applications. Its primary product is Neobee M-5, a medium-chain triglyceride (MCT) containing fatty acids obtained from mixed triglycerides in coconut oil.

Although only about 1 cal per g less than a typical fat, MCTs are metabolized more like carbohydrates, explains Joanne Kennedy, technical service representative at Stepan, and are burned for energy rather than stored. A drawback of MCTs is that, when hydrolyzed, the resulting free fatty acids have an "off" flavor that is difficult to mask. At this point, it is also not known whether these, and other alternative fats, will be considered as fats and counted toward total grams of fat and calories from fat on food labels.

This year, Pfizer began marketing a fat extender called Veri-Lo. Using a proprietary emulsion system in water, the fat-containing product forms gel particles. The particles are about the size of typical fat globules, says the company, and fat-coated so that Veri-Lo is perceived to taste and behave like fat while offering significant calorie reductions. Veri-Lo is a GRAS product intended for low-temperature applications such as mayonnaises, sauces, dressings, and dairy foods.

It is sold in two ready-to-use liquid forms for replacing 67 to 75% of fat. Veri-Lo 100 contains 33% soybean oil with 3.1 cal per g. Veri-Lo 200 contains 25% milk fat and 2.3 cal per g. Pfizer's products are a compromise between the flavor that fat contributes and fat reduction. Others in the industry acknowledge that making products without fat is difficult and that many may have serious flavor defects. Some even suggest that small amounts of fat, qualifying for low-fat rather than fat-free standards, may creep back into foods to compete with better tasting products.

Dynamic sweeteners market

Low-calorie sweeteners are another way of reducing calories in food. The expiration of NutraSweet's aspartame patent in December 1992 and the anticipated regulatory approvals of new high-intensity sweeteners make these one of the most dynamic, yet uncertain, of food-ingredient markets. Sweeteners are the largest segment of the calorie reduction products market in the U.S. at $1.07 billion in 1991, according to the Pathfinder report. Despite all the anticipated activity in this area, the market is expected to grow only 2.1% a year to $1.3 billion by 1996, primarily because of reduced pricing.

The market is dominated by aspartame (*N*-L-α-aspartyl-L-phenylalanine 1-methyl ester), which was approved

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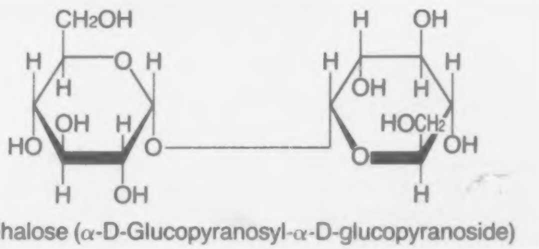

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Labeling laws to change information on food packaging

New food labeling regulations mandated under the Nutrition Labeling & Education Act (NLEA) of 1990 will have a major impact on the information consumers get about the food they eat. Proposed regulations from the Food & Drug Administration were released in late 1991 and will go into effect six months after a public comment period ends in November 1992.

The proposed regulations give guidelines for mandatory nutritional information on all processed foods. FDA repeatedly has expressed the desire to have labeling that is accurate, consistent, and credible while being understandable and useful to consumers. In addition to listing specific ingredients, labels will be required to include descriptive nutritional information, limits on health claims, and standard serving sizes on more than 130 categories of foods to allow for easier nutritional comparisons.

Listed on labels will be such items as total calories, total fat, calories from fat, cholesterol, total and complex carbohydrates, total sugars, dietary fiber, protein, sodium, vitamins A and C, calcium, and iron. FDA evaluated health claims as related to diet and will allow four to be included in labeling: calcium and its role in osteoporosis, sodium and its role in hypertension, and fat and its role in heart disease and its role in cancer. Precise definitions for terms such as "light" or "lite," "low," and "free" also would be established.

The proposed regulations define low fat as less than 3 g per serving and per [illegible] g, and fat free as less than 0.5 g per serving and per 100 g. Using the label, "X% fat free," would be possible only if a product meets the low-fat criterion, and "reduced fat" would apply to products in which fat has been decreased 50% and at least 3 g. The term light would refer to foods that are one third lower in calories than comparable non-calorie-reduced versions. "Low calorie" would refer to foods with less than 40 cal per serving and per 100 g. "Reduced calorie" foods would be required to be reduced at least one third and by at least 40 cal. When a product contains less than 4 cal per serving, it would be able to be called "calorie free."

Producers of fat replacers are opposed to what they consider overly stringent definitions proposed for light, says the Calorie Control Council in Atlanta. If 50% or more of a food's calories come from fat, there also must be a 50% reduction in fat in addition to a one-third reduction in

---

by FDA for table use and in dry beverage mixes in 1981. Since then, approvals have expanded its use into a range of product areas. In the U.S., aspartame is marketed by NutraSweet. Although it is metabolized in the human body, it is essentially noncaloric—because it has 180 times the sweetness of sucrose, only very small quantities are used.

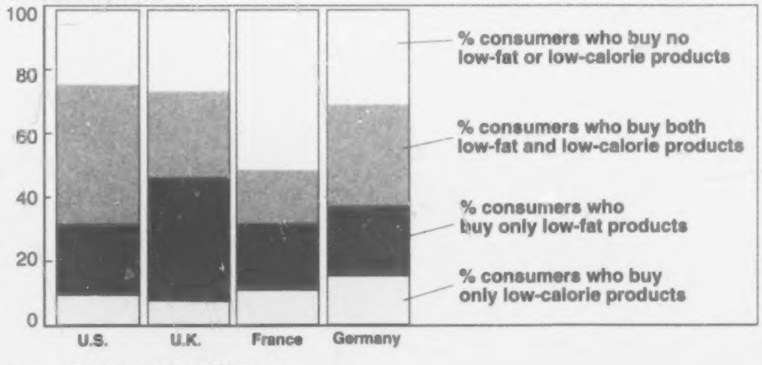
NutraSweet has aggressively marketed its sweetener, with customers displaying a NutraSweet logo on their products. This has contributed to 98% name recognition, says the company, and has helped position the product for the time when the patent expires. To maintain its head start and compete against generic forms to come on the market in the U.S., NutraSweet has been expanding production both here and overseas, and attempting to lower its production costs. Construction of a new French plant began in 1991 as part of a joint venture with Ajinomoto of Japan.

With a monopoly in the U.S., NutraSweet has been able to charge more than $50 per lb for aspartame. But pricing will be a driving factor here as it has been in Europe and Canada, where prices fell to about $30 per lb when patents expired. NutraSweet anticipates its sales to drop $250 million in 1993 because of a falloff in prices, rather than volume. However, Coca-Cola and Pepsi have signed long-term supply agreements with NutraSweet for use of aspartame in their diet soft drinks. With growing competition and estimated 30% price reductions for aspartame, the market for nonnutritive sweeteners in uses other than table use (such as for sweetening coffee or tea) is expected to decrease 4.5% a year, from $850 million in 1991 to $675 million by 1996, says Forman; however, volumes will increase.

In Europe and Canada, NutraSweet has faced competition from Holland Sweetener, a joint venture between DSM of the Netherlands and Tosoh of Japan. Based on a complaint from Holland Sweetener, the European Community imposed an antidumping fine of about $40 per kg on NutraSweet and Ajinomoto in 1991. With about 30% of the European market, Holland Sweetener has made clear its determination to enter the U.S. market, which accounts for about 80% of worldwide sweetener sales, and has been quadrupling production capacity to do so.

Competition is expected from other high-intensity sweeteners, which could get FDA approval in the next five years, although exactly when is uncertain. With more products available, Forman explains, prices might reach a

U.S. has highest consumption of low-fat, low-calorie products



Source: Calorie Control Council 1992 survey calories to warrant the term light. Reductions of 50% in fat are not feasible for all product categories, adds the council, or in some cases significant reductions are possible, but the food does not meet quantitative thresholds. And, reductions in both fat and calories may not be possible when fat is replaced with carbohydrates or proteins that contribute calories. The council proposes light apply to a one-third reduction in fat, with or without a reduction in calories.

A positive factor for low-fat or low-calorie foods may be a relaxing of the "standards of identity." The standards make it possible to call a food by a given name only if strict compositional definitions, sometimes including high levels of fat, are met. If not met, a product would have to use the terms "imitation" or "artificial." Because these terms lack marketing appeal, food processors had been discouraged from producing potentially healthier low-fat or low-calorie versions. Changes allowing a permitted nutrient descriptor with the name of a food—as in "low-fat ice cream"—are hoped to provide new incentives for food processors.

Reaction from the food industry to the basic FDA principles to move away from misleading labeling, such as those based on minuscule serving sizes, ranges from enthusiasm to resignation. Generally rejected, though, is the brief time given for compliance and completion of what is seen as a massive and costly task, as much as $4 billion according to food industry estimates, of relabeling foods. As part of the response, many companies and organizations have petitioned FDA to extend the time for implementation. The Department of Agriculture, which regulates marketing of meat and poultry products, has said it will set up similar rules, but will delay doing so until May 1994.

Many believe that once the initial task of compliance is over, food producers will be encouraged to develop more nutritional products that warrant desirable nutritional descriptions or claims on a label. At the same time, food processors are calling on FDA to streamline its approval process for new ingredients or additives, such as sweeteners and fat replacers, that might make these foods possible. However, as the number of additives continues to grow, there is little reason to believe FDA will become any less cautious in its approach to approval.

"sugar equivalent" of about $20 to $30 per lb. Further complicating the dynamics of the U.S. market is that FDA approvals often are food-application specific, such that two approved sweeteners may not compete directly in the same product areas.

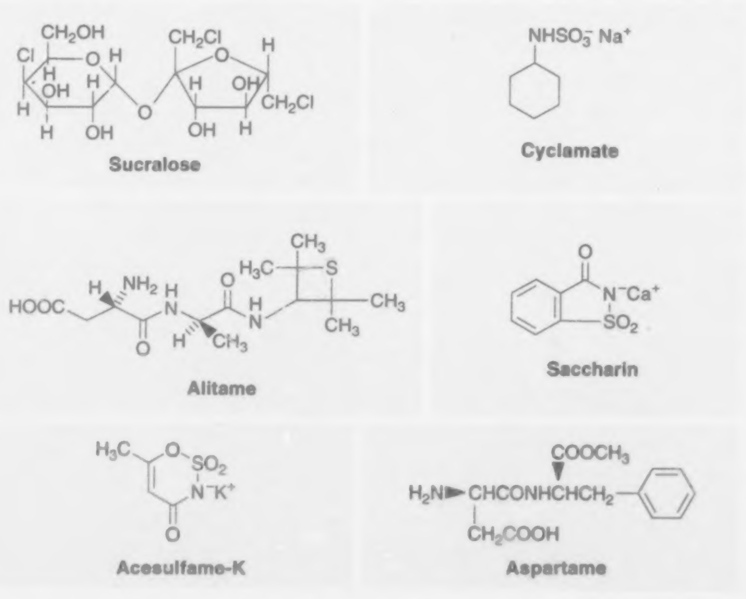
Baked goods are an untapped area targeted by many of the new products. One of aspartame's drawbacks has been its lack of stability under heat and/or acidic conditions. Last month, an encapsulated form of aspartame was approved in Canada for high-temperature applications and a similar application is pending in the U.S.

In 1988, after six years of review, FDA approved acesulfame-K (the potassium salt of 6-methyl-1,2,3-oxathiazin-4(3*H*)-one 2,2 dioxide) for use in dry mixes, table uses, and chewing gum. Unlike aspartame, acesulfame-K is heat stable and has a longer shelf life. Acesulfame-K is marketed by a division of Hoechst Celanese, based in Edison, N.J., under the Sunette tradename. It is used in more than 600 products in more than 35 countries and is awaiting FDA approval for other uses in the U.S. At 200 times the sweetness of sucrose, acesulfame-K is not metabolized and is noncaloric.

Because of what some view as its structural similarity to saccharin, a suspected carcinogen in animals, protests have been registered against acesulfame-K's initial approval in the U.S. Overseas, where there is a greater selection of available sweeteners, it has been successfully used in mixtures. Nonnutritive sweeteners frequently show a synergistic effect when used together, resulting in a sweetness level several times greater than the individual components. This allows for decreasing use levels, offers cost savings, and gives formulators a means to get desirable taste profiles under various conditions, minimizing the negative features of one sweetener while maximizing the positive aspects of another.

Also awaiting FDA approval are alitame and sucralose. Maybe closest to approval, according to Nabors of the

Variety of sweeteners used in low-calorie food formulations



Sucralose

Cyclamate

Alitame

Saccharin

Acesulfame-K

Aspartame

Use of flavors changes to meet demands of low-fat, low-calorie foods

The market for flavors has been affected greatly by the move toward low-fat, low-calorie, and convenience foods. Although consumers say they desire foods that are "healthier," an overriding demand is that foods taste as good as, if not identical to the real thing. For these new food formulations, flavor producers are using new technologies, including biotechnology, to come up with flavors. These new flavors are going into a wide range of markets including dairy, meats, seafood, and baked goods, and into many products that never before required their use.

Flavorings often are needed because reducing fat, sugar, salt, or calories leads to a decrease in palatability that is not supplied by replacement materials. In reduced-fat products, the challenge is to overcome not only the loss of flavor once provided by fat itself, but also the loss of functionality: Fat carries fat-soluble flavors and vitamins and, because of the "feel" it has in the mouth and its ability to linger there, it contributes to how flavors are perceived. Many food industry observers say the fatlike flavors and effects needed have not yet been achieved.

Fat also contributes flavors produced through cooking and/or frying. When foods are browned during cooking—known as the Maillard reaction—proteins, amino acids, fats, and carbohydrates react in the presence of heat. In order to produce these flavors in reduced-fat products, cooking processes or enzymatic reactions must be mimicked. Convenience products, such as those for the microwave, require flavors that develop quickly and are strong and stable enough to survive freezing and heating cycles.

Considerable changes are needed to formulate flavors for use in no-fat products, says Tracey Glancy, director of marketing and new business development at Imcera's and Hercules' 50-50 flavor joint venture. In February, the Fries & Fries flavor business of Imcera's Mallinckrodt Specialty Chemicals was combined with the PFW and citrus specialties flavor businesses of Hercules to form a yet-unnamed Cincinnati-based company. "We [also] have found that the same flavor doesn't necessarily behave the same way if the fat replacement system changes." To get satisfactory food formulations, flavor houses are working closely with customers, often on a product-by-product basis.

Some in the food industry put off by the added costs from flavors in new product formulations. An example Glancy gives is a lean hamburger for which flavors are needed when the fat is removed. "To people who have never used flavors, they look very expensive," she says. "Flavors sell in dollars per pound, but are used at very low levels. It is possible to use flavors in products like meats without making the price [of the product] prohibitive."

Overall, the market for flavors is anticipated to grow 6.2% annually, making it among the fastest growing food additive markets. It is estimated to grow from sales of $675 million in 1991 to $911 million by 1996, according to the Pathfinder report put out by the Business Research Group of Technomic Publishing Co. As has been the trend for several years, the demand for natural flavors outweighs that for artificial ones by 3 to 1, even though natural flavors tend to be less intense and less predictable when used in food products.

Calorie Control Council, is sucralose (1,6-dichloro-1,6-dideoxy-β-D-fructofuranosyl-4-chloro-4-deoxy-α-D-galactopyranoside), the only nonnutritive sweetener based on sugar. As a selectively chlorinated form of sucrose with a glycosidic linkage more resistant to acid or enzymatic hydrolysis, it is not metabolized. It has 400 to 800 times the sweetness of sucrose, has a high solubility, and is very stable to heat. It has been described as having a "high quality" of sweetness.

Jointly developed by Tate & Lyle and McNeil Specialty Products, a subsidiary of Johnson & Johnson, sucralose will be marketed in the U.S. by McNeil. It has been under review at FDA since 1987. In September 1991, Canada granted marketing approval in 13 food categories to an affiliate of Tate & Lyle for its Splenda sucralose product.

Alitame (L-α-aspartyl-*N*-(2,2,4,4-tetramethyl-3-thietanyl)-D-alaninamide) is another amino-acid-based sweetener, like aspartame, but includes a novel amine. Although it also is metabolized, at 2000 times the sweetness of sucrose, it is essentially noncaloric in use. Pfizer says alitame has a "sweet, clean taste." However, under acidic conditions at high temperature, it may have an "off" flavor. The company's petition for FDA approval has been pending since 1986, but review has been delayed by the need to repeat a study, says Nabors. Alitame's approval would round out Pfizer's position in the light food area.

Other heat-stable sweeteners are expected to displace saccharin (the calcium or sodium salt of 1,2-benzisothiazol-3(2*H*)-one 1,1-dioxide), which has been on the market for nearly a century and has survived a proposed FDA ban, overturned repeatedly by Congressional moratoria. Manufactured by PMC of Cincinnati, saccharin has 300 times the sweetness of sucrose. Despite a bitter aftertaste and the health controversy that has surrounded it, saccharin is used in a wide variety of applications.

FDA banned Abbott Laboratories' cyclamate (sodium cyclohexylsulfamate) in 1970, but the company has had a petition for reinstatement pending with the agency for several years. Results of animal studies that led to concerns of cancer and to the ban on cyclamates have been brought into question. Nabors is optimistic about its chances both for reapproval in the near future and about its reentering the market after having been banned. One disadvantage of cyclamate relative to other sweeteners is that its sweetness is only 30 times that of sucrose.

Other high-intensity sweeteners are in earlier stages of development, having not yet made it before FDA, or with limited approvals overseas. These include dihydrochalcones derived from bioflavonoids of citrus fruits; stevioside extracted from a South American plant; glycyrrhizin extracted from licorice root (used as a flavor enhancer in the U.S.); and thaumatin, a mixture of proteins taken from a West African fruit.

Left-handed sugars also are under development. These are not expected to be metabolized, but are expected to perform the same physically—providing the bulk, texture, taste, and cooking properties of normal sugars. ☐

CHEMICAL & ENGINEERING NEWS

C&EN

JUNE 22, 1992

A

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CFC SUBSTITUTES

USERS SCRAMBLE TO MEET 1996 PHASEOUT DEADLINE

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CHEMICAL & ENGINEERING NEWS

C&EN

JUNE 22, 1992

NEWS OF THE WEEK

- The Earth Summit in Rio de Janeiro ended with hope raised by progress in several areas but disappointment over failures in other areas. Page 4
- The U.S. House of Representatives votes to kill the Superconducting Super Collider, causing concern about whether science and technology will be hit further as budget pressures build. Page 5
- Launch of NASA's space shuttle *Columbia* later this week will initiate a series of Microgravity Laboratory missions to examine the effects of low gravity on crystal growth, fluid dynamics, and other processes. Page 5
- June 30 has been set for the split of Union Carbide into two separate companies, but a lawsuit threatens to scuttle the plan. Page 5
- NIH researcher Robert C. Gallo will speak this week about the controversy surrounding his lab's role in the 1984 discovery of the AIDS virus. Page 6
- A power shortage on NASA's Upper Atmosphere Research Satellite has shut down most instruments gathering data on the ozone layer. Page 6

COVER: Du Pont visiting researcher checks thermocouples on a freezer-evaporator in tests using chlorofluorocarbon substitutes carried out at Oak Ridge National Laboratory. Photo by Tom Cerniglio

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CENEAR 70 (25) 1–80
ISSN 0009-2347

BUSINESS

Japan's chemical industry hasn't enjoyed success of other high-tech areas despite visionary efforts. **Page 15**

Dow Chemical has launched $1 million program to promote plastics recycling. **Page 16**

GOVERNMENT

Reduction of waste generated at chemical plants yields environmental and economic benefits. **Page 18**

Bill would add severe criminal penalties to environmental regulations in effort to force companies to speed up their efforts to stop polluting. **Page 20**

SCIENCE/TECHNOLOGY

Research results show that ribosomal RNA is probably sufficient for peptide bond formation and that ribozyme catalyzes hydrolysis of aminoacyl esters. **Page 22**

Synthesis and characterization of two new derivatives of buckminsterfullerene are reported. **Page 24**

Exhibits at ACHEMASIA meeting in Beijing featured basic equipment and control systems; presentations emphasized energy problems and biochemical production. **Page 25**

BOOKS

"The Human Blueprint," by Robert Shapiro, explores how the human genome project became a major federally funded research undertaking. **Page 28**

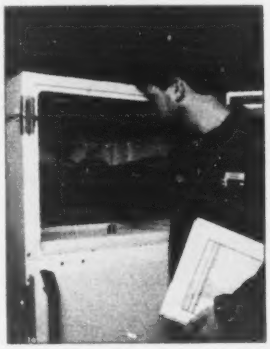
PRELIMINARY PROGRAM

ACS's 204th national meeting in Washington, D.C., in August offers variety of symposia; listing and highlights of symposia and full general program are included. **Page 31**

MEETINGS

C&EN's semiannual calendar of meetings and events lists scientific meetings and events through June 1993. **Page 63**

NEWS FOCUS



Pending ban on chlorofluorocarbons has industry and consumers alike preparing to use CFC alternatives in products ranging from refrigerators to metered-dose drug dispensers. Page 7

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

Incomplete photocatalytic oxidation of TCE

There has been recent interest and publicity regarding the use of UV-irradiated TiO_2 as a photocatalyst to destroy chlorinated chemicals in air. Publications have appeared regarding the destruction of trichloroethylene (TCE), a widely occurring contaminant in water and soils. Such experiments are easy to carry out in the laboratory at room temperature, using ordinary black-light fluorescent lamps and simple reactors with supported TiO_2.

This letter is to warn experimenters that the incomplete photocatalytic oxidation of TCE, perchloroethylene, and perhaps other chlorinated hydrocarbons in the gas phase over TiO_2 can yield considerable quantities of phosgene and chlorine. The phosgene has been unambiguously identified in three different reactors at the National Renewable Energy Laboratory using direct mass spectrometry and on-line Fourier transform infrared spectroscopy. From initial TCE concentrations of 100 ppm (volume) in moist or dry air, phosgene concentrations up to about 75 ppmv were seen at 98% TCE destruction (chlorine concentrations were comparable). This is well above the threshold limit value of 0.1 ppmv. In initial studies by others using gas chromatographic (GC) analysis [see, for example, *Environ. Sci. Technol.*, **26**, 492 (1992)], phosgene and chlorine have not been reported, perhaps because of the sample collection procedures or the GC columns used. We are raising a laboratory safety issue and not passing judgment on the ultimate potential of the technology, since process solutions exist to prevent formation of, or to remove, such by-products.

Tom Milne
Mark Nimlos
Chemical Technologies Research Branch
National Renewable Energy Laboratory
Golden, Colo.

MSDS database

Janice Long (C&EN, May 18, page 7) has provided a comprehensive, timely description of the proposed standard for the preparation of material safety data sheets (MSDSs). The standard is an impressive accomplishment of the Chemical Manufacturers Association and its MSDS work group. The benefits of the standard for health and safety and for international trade will likely far outweigh the sizable costs of implementing the standard.

The article closes with the comment that many chemical users have asked for a centralized source of MSDSs. One centralized source of MSDSs already exists and is widely available at reasonable cost. This is the MSDS database produced by the Canadian Centre for Occupational Health & Safety (CCOHS).

During the past 10 years, CCOHS has worked in consultation with chemical producers and users to build a database containing over 80,000 MSDSs from over 470 North American chemical suppliers. The database reproduces the complete texts and formats of MSDSs exactly as they are provided by chemical suppliers. Most MSDSs are submitted in electronic form as text files, following simple specifications. MSDS collections are updated simply by providing a new text file with new content and/or format.

The MSDS database is available throughout the world on-line on STN International as "MSDS-CCOHS." It is also available on CD-ROM from CCOHS. In these forms, it has over 2500 users in about 40 countries.

As yet, the MSDS database contains only a fraction of all existing MSDSs, but it continues to grow as suppliers and users recognize its value in helping to comply with occupational, environmental, and right-to-know requirements.

The database is produced and distributed at moderate cost because of the voluntary participation and excellent cooperation of suppliers. Administrative overhead is low, and most of the subscription income is used to process new collections and updates.

Robert Whiting
Manager, Chemical Database Development
Canadian Centre for
Occupational Health & Safety
Hamilton, Ontario, Canada

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NEWS FOCUS

Industry, Consumers Prepare for Compliance with Pending CFC Ban

Everything from refrigerators to metered-dose drug dispensers will likely be affected by move from chlorofluorocarbons to alternatives

Pamela S. Zurer, C&EN Washington

For chlorofluorocarbons (CFCs), doomsday is now only three and one half years away. Last February, President Bush—prompted by new evidence of the continuing deterioration of the stratospheric ozone layer—unilaterally moved the deadline for the U.S. to cease production of CFCs and other ozone-depleting chemicals from the year 2000 to the end of 1995.

For the myriad industries, businesses, and consumers that have relied on CFCs, the ramifications of the coming demise of the chemicals vary. Some have already identified substitute chemicals, processes, and technologies, and have eliminated all CFC use. Others are well on their way. Some are poised to take the plunge once questions about the safety and environmental acceptability of certain substitutes are cleared up and their relative price goes down.

However, still other CFC users, most notably manufacturers of household refrigerators, were already struggling to meet the previous phaseout deadline of 2000. The loss of four years in which to engineer and test replacements has them anxious and worried.

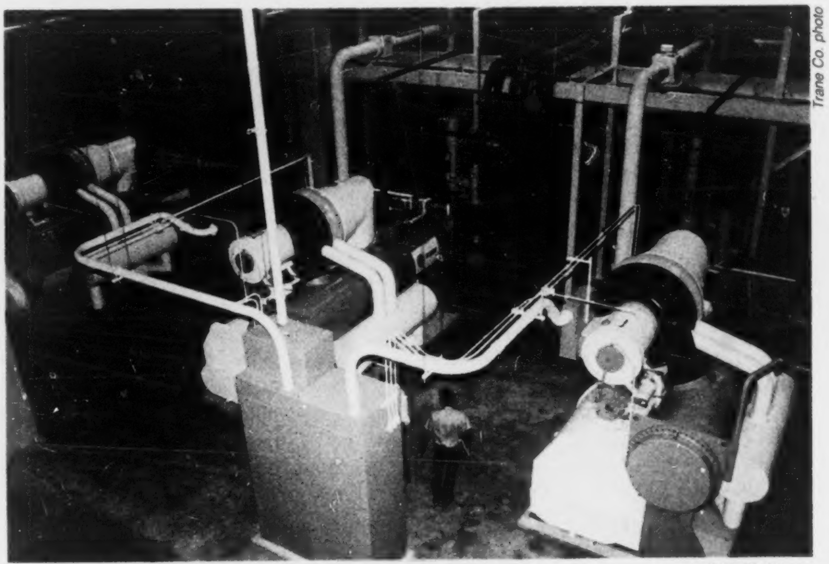
Complicating matters further, some hydrochlorofluorocarbons (HCFCs) that are being substituted for CFCs will themselves be phased out early in the next century. Rapid replacement of CFCs with HCFCs and hydrofluorocarbons (HFCs) is necessary to achieve an early phaseout of CFCs, according to United Nations-sponsored assessments. But HCFCs carry some chlorine into the stratosphere, although they are less damaging to the ozone layer than fully halogenated compounds. That means they face a ban sooner or later, and certain industry sectors must look for a second set of alternatives, this time for the HCFCs.

The brief history of CFC regulation is a tale of policymakers struggling to keep up with a stream of bad news about the stratospheric ozone layer, which blocks most damaging solar ultraviolet radiation from reaching Earth's surface. When the negotiations that eventually led to the Montreal Protocol on Substances That Deplete the Ozone Layer began in the mid-1980s, the atmospheric science community believed controlling the growth in production of CFCs and halons (fluorocarbons that contain bromine) would be enough to ward off significant ozone destruction.

Thus, the original terms of the treaty, agreed to in 1987, called for a cutback in CFC production to 50% of 1986 levels by 1998. The output of halons was to be frozen at 1986 levels in 1992.

But the treaty was out of date well before it went into effect in 1989. By then, scientists had confirmed that chlorine and bromine from CFCs and halons are the cause of the recurring dramatic seasonal losses of ozone at the South Pole known as the Antarctic ozone hole (C&EN, May 30, 1988, page 16). Moreover, a careful evaluation of measurements taken from Earth and from satellites had revealed a small but ominous erosion of the ozone layer all over the globe (C&EN, March 21, 1988, page 6). And research in the Arctic found the stratosphere there chillingly similar to the Antarctic's, with only the milder northern winters thus far preventing significant ozone depletion (C&EN, March 6, 1989, page 29).

Those findings led the international community to


Trane Co. photo

These chillers for air-conditioning large buildings use HCFC-123 in place of CFC-11 strengthen the Montreal protocol. Its 1990 London amendments require complete phaseout of CFCs, halons, and carbon tetrachloride by the end of the century. Methyl chloroform (CH_3CCl_3) is to be banned by 2005.

In the U.S., the 1990 Clean Air Act imposed similar controls, although its deadline for a methyl chloroform phaseout is 2002. The U.S. law differs significantly from the international treaty, however, in how it treats HCFCs. The London amendments call for voluntary phaseouts of "transitional substances" (HCFCs) no later than 2040, whereas the Clean Air Act forbids production of HCFCs after 2015 except for servicing existing equipment and imposes a total ban after 2030.

The Clean Air Act also requires U.S. officials to speed up the phaseouts if necessary to protect human health and the environment. It was under that authority that President Bush in February ordered the end of CFCs, halons, carbon tetrachloride, and methyl chloroform production four years earlier than planned (C&EN, Feb. 17, page 5). He also called for a review of HCFCs and of methyl bromide, recently identified as a major source of bromine in the stratosphere.

Bush acted after the National Aeronautics & Space Administration announced in February that global ozone erosion was occurring faster and extending farther than previously believed. Scientists taking part in NASA's second airborne research expedition over the Arctic also concluded there is a high likelihood of an ozone hole developing in the Northern Hemisphere during the next 10 years (C&EN, Feb. 10, page 4).

Their findings bolstered the conclusions of last year's "Scientific Assessment of Ozone Depletion: 1991," prepared for the United Nation's Environment Program (UNEP) by an international panel of 80 scientists. That report, meant as advice to the countries that are parties to the Montreal protocol, concluded that stronger restrictions on chlorine and bromine compounds are necessary to head off even worse losses of ozone in the next decade.

So once again the Montreal protocol member nations will strengthen the treaty. When they next meet in Copenhagen in November, they are expected to vote to accelerate the CFC and halon phaseout deadline to sometime in 1995 and to place as yet undetermined restrictions on HCFCs.

Making such a quick shift away from CFCs is technologically feasible, according to another 1991 UNEP study for the treaty nations. Virtually all new production—although not the use of recycled chemicals—of CFCs, halons, carbon tetrachloride, and methyl chloroform could be eliminated in industrial nations by 1995 to 1997, the report concludes.

"There are lots of good reasons to be optimistic," says Stephen O. Andersen, director of the Environmental Protection Agency's technology transfer and industry programs in the division of global change. Andersen was cochairman of UNEP's technology and economic assessment panel, which was composed of 240 members from 38 countries—the majority of whom were from industry.

"Worldwide, CFC production is already 40% below 1986 levels," he points out. "That's way ahead of the game. Progress has been faster even than what we thought was feasible when we did our last assessment in 1989."

Andersen points to several success stories that demonstrate that getting out of CFCs is proven and feasible. The assessment panel could not find a single producer of plastic foam food-packaging products anywhere in the world that is using CFCs, he says. In the U.S., that industry completed the switch to HCFC-22 ($CHClF_2$) and hydrocarbon blowing agents in early 1990, according to the Foodservice & Packaging Institute.

C&EN staff photo

Metered-dose inhalers use CFCs to propel medication into lungs

The panel for the first time also identified entire companies, even entire countries that have quit using CFCs. In early 1992 Northern Telecom became the first multinational corporation to halt all use of CFCs in its operations. And Sweden has remaining only one small military application for the chemicals, Andersen says.

"It's not pure proof that CFCs can be eliminated entirely," he says. "Surely Sweden could still be importing products made with CFCs. No doubt Northern Telecom still buys products made with CFCs. Nevertheless it is an incredible accomplishment."

The electronics industry as a whole has made rapid progress. It had been a heavy user of CFC-113 (CCl_2-$FCClF_2$), once the fastest growing segment of the CFC market, for cleaning printed circuit boards and other electronic components. Now, virtually all major electronics companies have pledged to eliminate CFC use by 1995, if not earlier.

To clean their products, researchers in the industry have developed aqueous and terpene-based solvents, among others. And in the quest for substitute chemicals, they also have found alternative processes and technologies—some of which are turning out to be money savers. The rewards from eliminating CFCs will become even greater during the next few years as the chemicals' prices rise as a result of shrinking supply and an increase in the taxes the U.S. imposes on them.

AT&T, for example, has patented and is marketing a "low solids fluxer," a system that entirely eliminates the need to clean electronic circuitry after soldering. The initial cost of buying the equipment, the company claims, is recovered in less than a year.

In 1988 the electronics industry formed the Industry Cooperative for Ozone Layer Protection (ICOLP), in an effort to share advances and promote technology transfer among countries and companies. ICOLP acts as a clearinghouse for information on CFC alternatives and sponsors a database called OZONET used by companies, governments, and associations.

Such access to information will be key to getting other users of CFC-113 and methyl chloroform to give up those chemicals. Both solvents are widely used in small manufacturing and service shops for cleaning metals, for example.

"Larger users and customers have seen this on the horizon and are finding alternatives," says Ken Gedaka, a spokesman for Dow Chemical, which produces methyl chloroform. "It's harder for the smaller businesses. They don't have the capital or resources to search for substitutes or even the staff to monitor the constantly changing regulations. The mom and pop shops are nervous, indeed."

Also nervous is the American Lung Association (ALA). At its annual meeting last month, the association announced it's seeking an exemption from Bush's accelerated phaseout schedule for the CFCs in the pocket-size devices used by patients suffering from asthma, chronic bronchitis, and emphysema. ALA estimates about 25 million people in the U.S. use metered-dose inhalers, which deliver precisely measured doses of medication in aerosol form directly to the lungs. CFCs are the propellants.

The pharmaceutical industry is looking for new propellants, as well as for alternative delivery systems like dry powder inhalers. It is concentrating on two HFCs, but neither is fully compatible with all current drug formulations or device designs.

Once substitute propellants are identified, the drug companies must demonstrate to the Food & Drug Administration that they are safe and that formulations using them are effective. ALA estimates the shortest possible time needed for conversion to CFC-free inhalers is six to eight years—1998 to 2000.

In announcing the accelerated ban last February, Bush said the Administration would allow limited production of CFCs after 1995 if necessary to sustain essential uses. The White House specifically cited medical uses as a possible exemption, along with refrigeration and air-conditioning. Such exemptions are also being considered as part of the latest amendments to the Montreal protocol. In the U.S., EPA has said it will not define what essential uses will be exempt from the phaseout until 1994 at the earliest.

Another anxious group of CFC users who have asked for an exemption from the 1996 deadline are producers of home refrigerators. Besides being forced to move away from CFCs, the home appliance industry is facing stiff federal energy-efficiency requirements. So far, no U.S. manufacturer has switched to substitutes.

Refrigerator manufacturers use CFC-11 (CCl_3F) in the polyurethane foam insulation that fills the walls and doors of such units. The CFCs trapped within the foam contribute to its insulation value. Refrigerators also have CFC-12 (CCl_2F_2) in their compressors. Although the amounts of the chemicals per unit are small and make up only a modest part of the final cost of the product, the CFCs perform essential roles.

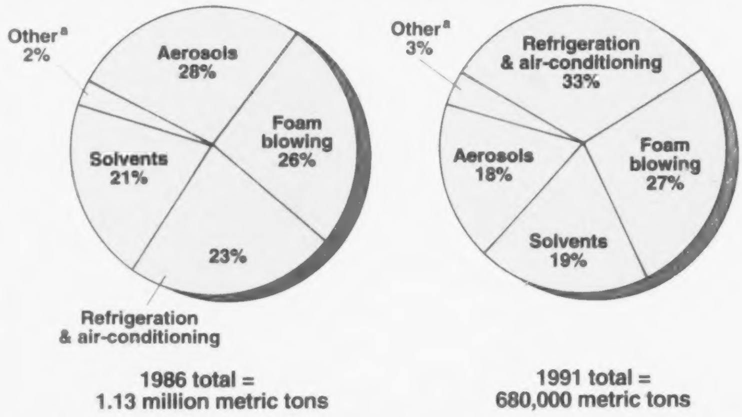
"CFCs are fundamental: They are the blood and bones of our product," says Charles Samuels, government relations counsel for the Association of Home Appliance Manufacturers (AHAM). "There's tremendous concern within the industry. We'll be the last to move out. There are significant technological and economic barriers to overcome and our members are moving with extreme caution."

Although modifications in the foaming process are allowing refrigerator manufacturers to reduce the amount of CFC-11 they've been using, they are facing major headaches getting rid of it entirely. The Appliance Research Consortium, a subsidiary of AHAM, has found that two of the most promising substitutes, HCFC-123 ($CHCl_2CF_3$) and HCFC-141b (CH_3CCl_2F), attack the plastics currently used as interior liners. They also weaken the elastomers used in items such as seals, gaskets, and O-rings.

"We've found some serious liner cracking that can't be repaired," Samuels says. "The financial consequences of liner problems developing after a few years are staggering. We make 25,000 refrigerators a day that people expect to last for 15 or 20 years with virtually no repairs. The warranty costs could be potentially disastrous."

The incompatibility problems likely can be solved by switching to different plastics and elastomers. But both HCFC-123 and HCFC-141b face additional difficulties. Last summer, despite having looked innocuous in the first rounds of toxicity tests, HCFC-123 was found to cause benign tumors in male rats (C&EN, July 22, 1991, page 21). Although it likely can be used safely in applications where

Worldwide CFC output in 1991 was 60% of 1986 level



[a] Primarily sterilants and medical uses. **Sources:** United Nations Environment Program, 1991 Report of the Technology & Economic Assessment Panel; C&EN estimates

Atmospheric chlorine levels, ozone threat will peak around turn of the century

The need for quick action on scrapping chlorofluorocarbons (CFCs) and other ozone-depleting compounds stems from their long atmospheric lifetimes. Even though their use is now being curtailed, atmospheric chlorine concentrations will continue to increase for about another 10 years because of the lag between the time CFCs are manufactured and when they reach the stratosphere. And even when their concentration begins to decrease, it will take decades for their levels to fall below those at which ozone destruction was first observed. Atmospheric scientists are very worried about what might happen in the meantime.

The situation can't get much worse over Antarctica. When the Antarctic ozone hole was first discovered in the mid-1980s, it waxed and waned from year to year. For the past several years, however, the destruction of ozone over Antarctica in the spring has been consistently deep and extensive in area, according to the 1991 scientific assessment prepared for the United Nations Environment Program.

During September and October, essentially all the ozone in the Antarctic stratosphere is chewed up in chain reactions catalyzed by chlorine and bromine free radicals. (The ozone is eventually replenished as shifting springtime winds bring ozone-rich air from lower latitudes.) So, although the depletion there could widen geographically, it can't get more acute than it already is.

The Arctic is another story. During last winter's NASA-sponsored second Airborne Arctic Stratospheric Expedition (AASE II), scientists observed record high levels of chlorine monoxide, the free radical that is vital in key ozone-destroying reactions. The ozone-depletion cycle requires sunlight, however, and this year, an early warming in the polar regions allowed the chlorine monoxide to dissipate before the far north became strongly sunlit.

Nevertheless, a NASA satellite recorded a decrease in ozone of about 10% in certain Arctic regions last winter. "That is not an ozone hole, but it is a significant loss of ozone," Harvard chemistry professor James G. Anderson, who was chief scientist for the expedition, said this past April.

Arctic ozone depletion will most likely worsen in the coming decade. Chlorine concentrations will likely continue to increase for about 10 years and, because five out of 10 Arctic winters are colder than the winter of 1991-1992 was, during many of those years it will be cold enough, long enough for the chlorine to do serious damage.

A less acute but more pervasive loss of ozone over the rest of the globe also must be reckoned with, says Michael Kurylo, head of NASA's upper atmospheric research program. Ground and satellite observations show that winter ozone levels at northern midlatitudes decreased 6 to 8% between 1979 and 1991. Smaller but still troubling decreases have been recorded in spring and summer as far south as 30° N. Although not so dramatic as the Antarctic ozone hole or the threat of an Arctic hole, these losses are occuring over regions and in seasons where people, animals, and crops could be exposed to increased levels of damaging ultraviolet radiation.

Data from AASE II provide strong evidence that midlatitude losses are caused by chlorine- and bromine-cata-

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exposures can be controlled, EPA is expected to forbid its use in foams when the agency proposes "safe alternatives" regulations later this summer.

Thus far, no such unhappy surprises have turned up in toxicity tests of HCFC-141b, which—like those on HCFC-123—are expected to be completed later this year. Use of HCFC-141b, however, is likely to be restricted because it has the highest ozone-depleting potential of any of the major CFC alternatives.

A ban on use of HCFCs-22, -141b, and -142b in new equipment by 2000 is among the demands of a coalition of three environmental groups. The Natural Resources Defense Council, Friends of the Earth, and the Environmental Defense Fund petitioned EPA last December to speed up the U.S. phaseout of ozone-depleting chemicals (C&EN, Dec. 9, 1991, page 5). They want those three HCFCs banned entirely by 2005.

EPA was supposed to have responded to the groups' petition by June 3, but missed its deadline. Eileen Claussen, director of EPA's office of atmospheric and indoor air, says the agency will include its answer to the environmental groups when it proposes regulations to implement President Bush's accelerated phaseout.

EPA's proposal will also respond to a February petition by the Alliance for Responsible CFC Policy. The alliance, a Washington, D.C.-based industry-trade group composed of CFC producers and users, countered the environmental groups' demands with its own recommendations on HCFCs. It seeks a ban on production for new equipment in 2010, with a total phaseout by 2020.

The alliance argues that those dates would clearly signal users that HCFCs cannot be relied on as the final answer to replacing CFCs. Yet the deadlines are far enough in the future to make investment in converting to HCFCs worthwhile, while research on the next generation of substitutes continues, it says.

Rumor has it EPA is going to propose a compromise between the dates suggested by the environmental groups and the industry group, restricting HCFCs-22, -141b, and -142b use to the maintenance of existing equipment after 2005. The proposed regulations may be out within a month, though they have yet to be cleared by the Office of Management & Budget.

EPA also is supposed to publish sometime this summer a list of prohibited substitutes for particular CFC uses. Under the Clean Air Act's safe-alternatives policy, the agency must weigh both the environmental and health effects of compounds that are replacing CFCs. The rule making is complicated, Claussen says, because her staff is looking at individual chemicals and industry sectors on a case-by-case basis.

Because of its potential toxicity, for example, HCFC-123 is expected to be approved for cooling uses but not for foams or solvents. HCFC-141b, on the other hand, could be banned from solvent use because of its relatively high ozone-depleting potential.

At the pace it's moving, EPA no doubt will miss its statlyzed reductions. Reactions on sulfate aerosols shift the equilibria within families of nitrogen, chlorine, and bromine species toward the active, ozone-destroying forms. And that condition will only get worse as the atmospheric halogen concentration increases during the 1990s.

"We believe we'll see about double the midlatitude loss in the next decade," says Robert T. Watson, director of NASA's process studies program office. "The international assessment of last October combined with the findings of the [AASE II] campaign clearly show the London amendments are inadequate to protect ozone in the future."

Under the London amendments—the 1990 revisions that strengthened the Montreal Protocol on Substances That Deplete the Ozone Layer—chlorine levels in the atmosphere would grow from the current 3.5 ppb to around 4.0 ppb by 2000 and then slowly decrease. Chlorine concentrations would decline to 3 ppb by about 2027 but would not go below 2 ppb, the level at which the Antarctic ozone hole first appeared, until the second half of the 21st century.

HEY, YOUR OZONE IS GETTING PRETTY THIN ON TOP!
I TRIED COMBING IT UP FROM THE EQUATOR, BUT THAT DIDN'T WORK.
THAVES 4-6
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Strengthening control measures by moving phaseout deadlines forward and making interim cuts in use can both decrease the future peak chlorine concentration and speed the rate at which the concentration declines, Watson says. Regulating hydrochlorofluorocarbons (HCFCs), which are replacing CFCs in several uses, would also help chlorine levels to decline faster.

HCFCs share many of the desirable characteristics of fully halogenated CFCs, but not their long lifetimes. The hydrogen atoms they bear make them susceptible to oxidation in the lower atmosphere, so over the long term they have a much lower potential for depleting the ozone layer.

But a portion of emitted HCFCs do enter the stratosphere and once there release chlorine atoms that destroy ozone. Although their brief lifetimes mean the atmosphere could recover quickly from large emissions of HCFCs, the short-term damage could be significant, according to a recent study by National Oceanic & Atmospheric Administration scientists Susan Solomon and Daniel L. Albritton [*Nature*, 357, 33 (1992)]. And it is in the short term—the next few decades—that danger to the ozone layer will be most acute. These scientists suggest considering restrictions on the production and use of HCFCs that have the largest short-term potential for ozone depletion.

utory deadline to finalize safe alternatives rules by Nov. 15. It has already missed deadlines for regulations regarding CFC labeling and recycling. The delays dismay not only environmental groups, but industry too.

"EPA needs to publish regulations as soon as possible," says F. Tony Vogelsberg, Du Pont's environmental manager for fluorochemicals. "We have seen reluctance in customers to switch out of CFCs. They're concerned whether the safe alternatives program will deem a particular use acceptable."

The uncertainty over how long HCFCs will be on the market is also a sticking point for current CFC users. "EPA needs to give users some clarity so they can make plans and move ahead. Owners of apartment buildings, office buildings, or grocery stores need [to believe] that you will be able to use HCFCs long enough to justify investment in conversion," Vogelsberg says.

Despite the regulatory uncertainty surrounding HCFCs, President Bush's acceleration of the CFC phaseout schedule is prompting some users to switch. For example, Trane Co. sells large centrifugal water chillers—air-conditioning units for big buildings—that can function with either CFC-11 or HCFC-123. The company has noted a significant change among its customers since Bush's February announcement.

"Last summer, about 10% of the machines we were shipping contained the alternative," says Gene Smithhart, Trane marketing manager. "For the first quarter of this year, it was 30-plus %. We expect half of the orders we ship in the next six months will use HCFC-123. And by next year, we think that will be up to 80 or 90%."

Price is another factor that soon will motivate CFC users to buy alternatives. Currently HCFC-123 and HCFC-141b cost around $2.00 per lb. When the federal tax of $1.37 per lb is added to the average CFC cost of about 75 cents per lb, CFCs cost roughly the same as these HCFCs. However, the tax on CFCs is set to almost double next year, making CFCs decidedly more expensive for the first time.

Makers of rigid foam board insulation are poised to eliminate use of CFCs, but most have not yet done so. Facing competition from fiberglass and expanded polystyrene in new construction, manufacturers of rigid polyurethane and polyisocyanurate need a CFC-11 substitute with good insulating properties. (In contrast, flexible-foam manufacturers—who don't need to worry about insulation values—have already largely replaced CFCs with water-blown foams.)

HCFC-141b is turning out to be almost as good an insulator as CFC-11, says Lorraine Aulisio, Celotex Corp.'s vice president for technical services. "The industry has made a commitment to be out of CFCs by the end of 1993, and we likely will make it."

The blowing agent's cost is a significant part of the cost of their products, she says, but HCFC-141b has been found to be more efficient than CFC-11, so not as much is needed. And with CFC taxes going up, HCFC-141b will soon be cheaper anyway.

The fact that toxicity tests on HCFC-141b have not been

Halons: money in the bank

When the Montreal Protocol on Substances That Deplete the Ozone Layer was first negotiated in 1987, halons (fluorocarbons that contain bromine) were considered so essential for fighting fires that their production was subjected only to a freeze, not a mandatory decrease. When the Montreal protocol was strengthened in 1990, they were placed in the same category as CFCs and scheduled to be phased out by 2000—but with exemptions allowed for essential uses. However last year, when a United Nations Environment Program (UNEP)-sponsored study was asked to list what were essential uses of halons and should be exempt from the ban, the panel decided there was no need to make such a list.

"There is so much halon already that it will last well into the next century if it is carefully banked and conserved," says Stephen O. Andersen, the Environmental Protection Agency director of technology transfer and industry programs, who cochaired UNEP's technical and economics assessment panel. "The solution is not to manufacture more halon but to set up a system for redeployment."

Very little of current halons production is actually discharged to fight fires. Instead, most is stored in tanks in the fire-protection systems of buildings, airplane cockpits, or military equipment. In the past few years, fire codes have been changed so that discharge testing of the systems now is done with surrogate chemicals rather than halons.

The major hurdles to phasing out halons production are management, not technical challenges, Andersen says. A halons banking system would allow users to withdraw the chemicals when needed as well as to dispose of them in an environmentally sound way by making deposits in the proposed bank. UNEP's halons banking committee is studying the issue and may recommend allowing international trade in recycled halons.

completed is holding back some potential users—and suppliers—of the chemical. So far there are no indications of toxicity problems with HCFC-141b. But industry is being cautious because insulation is used in buildings where people potentially could be exposed to it for decades.

"We're not selling this product into the rigid-foam market until we have the final toxicity data in the [upcoming] fourth quarter," says William Corcoran, Allied-Signal's vice president for public affairs, engineered materials sector. "There's a lot of pent-up demand. The transition won't be slow and gradual but more like instantaneous."

Unlike HCFCs, the second major group of CFC substitutes are not in regulatory limbo. Although they must clear toxicity hurdles, HFCs pose no threat to the ozone layer because they contain no chlorine. However, they are much more expensive, about $10 per lb.

HFC-134a (CH_2FCF_3) already is being used in a few new automobile air conditioners in place of CFC-12. U.S. car manufacturers plan to gradually phase it into all their models during the next few years.

"When you look under the hood you won't see that much difference," says Gerald Stofflet, General Motor's assistant director of automotive emissions controls. Stofflet is chairman of the Motor Vehicles Manufacturers Association's CFC subcommittee. "But using HFC-134a involves a major redesign, not just [of] the compressor. We had to look at every part of the system. [HFC-134a] operates at higher pressure and needs a new lubricant."

Stofflet sees a looming problem in servicing the air conditioners in older cars and trucks once CFC-12 is no longer available. Car manufacturers have been upgrading the hoses and O-rings in air-conditioning systems since the late 1970s, he says. "There are a lot of cars on the road that all have different materials. We're now looking for new refrigerants and lubricants that would be compatible. If you put 134a and its lubricant into a system designed for CFC-12, you will reduce the durability of the system significantly."

Retrofitting older cars will also require a new desiccant, he says. The industry thinks the cost will be around $200 per car. For that money car owners will get a system that never cools quite as well as it did when operating with the CFC-12 it was designed for.

HFC-134a also will replace CFC-12 in home refrigerator compressors. It's already in use in a few models in Europe and New Zealand, according to EPA's Andersen. Not all the kinks in the new systems have been worked out yet, however, says AHAM's Samuels.

"We've seen some coking and caking of the compressor with HFC-134a," Samuels says. "It's not a drop-in replacement for CFC-12. There must be a different compressor, new lubricant, and new desiccator. A refrigerator's compressor operates as much in a year as a car's does in a lifetime."

EPA and the Electric Power Research Institute have been sponsoring longer term research aimed at identifying other possible alternatives for CFC and HCFC refrigerants. For example, chemists at Clemson University and the University of Tennessee synthesized a variety of fluorinated propanes, butanes, and ethers that contain neither chlorine nor bromine.

Eleven of the candidates—nine hydrofluoropropanes and two hydrofluoroethers—have been selected by researchers at EPA's Air & Energy Engineering Research Laboratory in Research Triangle Park, N.C., for further evaluation. All these fluorinated compounds have boiling points and critical temperatures that come close to those of fully halogenated CFCs. Computer models indicate the potential substitutes could be more energy efficient than currently used CFC refrigerants.

The Department of Energy's Oak Ridge National Laboratory (ORNL) is comparing the thermodynamic performance of possible refrigerant alternatives in standard refrigerators and heat pumps. "We set up standard operating conditions and run various refrigerants or mixtures of refrigerants through their paces," says Van Baxter, group leader for refrigeration systems at ORNL's building equipment research program.

Baxter's group also is working with the Appliance Research Consortium on the mechanical systems in refrigerators. "We are looking at some of the leading candidates to see if we can optimize the cycle technology," he says.

EPA also is funding research on alternatives to HCFC-22, which is used in home air conditioners and many commercial refrigeration systems and will eventually be phased out. Researchers at the University of Maryland, College Park, have concluded that blends containing HFC-32 (CH_2F_2) are likely candidates.

Both the auto air-conditioning and home appliance industries are about to face new requirements for capturing, reclaiming, and recycling CFCs during servicing. EPA will issue final rules for mobile air-conditioning any day now, whereas regulations for other uses will be proposed later this summer.

Many shops that service auto air conditioners already are trapping and recycling CFC-12, even though the federal regulations are not yet in place. "In the past two years, more than $1 billion worth of recycling equipment has been sold," says Andersen. The shops that have bought it, he says, are saving time and money, and providing technically better service.

"Some large companies—such as Firestone, Sears, Ford, and GM—made it company policy not to vent CFC-12 in their repair shops," he notes. "Other independent shops converted because their customers asked them. Having your car serviced properly has been the biggest single thing an individual consumer could do in the U.S. to help the environment."

The change to capturing and recycling CFCs from appliances may not go so smoothly. The Clean Air Act states that after July 1 it will be illegal to vent CFCs or HCFCs to the atmosphere during repair, maintenance, or disposal. EPA, however, has not yet published even a draft of the rules enforcing that section of the law.

EPA is expected to require service technicians to be certified and to use registered equipment that meets set standards. It likely will impose large fines for each instance in which the chemicals are allowed to escape. The agency has worked closely with industry in developing its proposals, so most big companies know more or less what to expect. But that's not necessarily the case for smaller operators.

"Most technicians are independent small businesses," says Samuels. "Many probably don't even know the certification requirement is coming. There's an enormous shortage of recovery equipment."

Trane Co., which sells all sizes and types of air-conditioning equipment, says it and other companies plan to offer training for technicians on a massive scale. "It is no longer business-as-usual in servicing refrigerants, handling refrigerants, or installing refrigerants," says Trane's Smithhart.

"We should have been doing this as an industry for years and years," he says. "In reality this is good business. Not only is it environmentally correct not to blow a charge of CFCs, but it is economically sound. It costs less to do it right than to do it wrong."

One Minneapolis-based company, Appliance Recycling Centers of America (ARCA), already is successfully recovering and reclaiming CFCs from unwanted household appliances. The firm contracts with electrical utilities to pick up old, energy-inefficient appliances from the power companies' customers. ARCA then drains the CFC-12 from refrigerator compressors, cleans it up in its own distillation facility, and sells it.

"Up until about six months ago, there wasn't much enthusiasm for buying recycled and reclaimed CFCs," says ARCA president Jack Cameron. "Now the price has gone up and the supply has gone down. We can't get enough CFC-12 to sell."

ARCA is about to begin recovering CFC-11 from the foam insulation in refrigerators. This fall it will install a system developed by Adelmann of Karlstadt, Germany, that has a certified recovery rate of 99%, Cameron says. In this system, the foam insulation is placed in a chamber under negative pressure where it is shredded and crushed. The pulverizing breaks the bubbles in the foam, releasing CFC-11, which then is removed in a degasification process.

"We feel real good about this," Cameron says. "There's more CFC-11 in the foam than there is CFC-12 in the compressor. And the CFC-11 can be purified without too much trouble."

"There are tremendous business opportunities for people who get going," EPA's Andersen says. "There's a major concern that delay or neglect in moving out of CFCs will lead to shortages in 1995 or 1996. Shortages not just of chemicals, but of capital equipment and trained people to help make the transition.

"Early demand for substitute chemicals and technologies would help companies develop the necessary manufacturing facilities and train technicians and installers. There is time right now to make the transition. There won't be time if you wait too long." ☐

Some CFC alternatives also face restrictions

Substance	Ozone depletion potential[a]	Major uses	Regulatory outlook
HCFC-22 ($CHClF_2$)	0.055	Foams, air-conditioning, refrigeration, aerosols	Clean Air Act bans aerosol use after 1993; EPA likely to ban use in new equipment after 2005
HCFC-142b (CH_3CClF_2)	0.065	Foams, refrigeration	EPA likely to ban use in new equipment after 2005
HCFC-141b (CH_3CCl_2F)	0.11	Foams, solvents	EPA likely to approve for foam use only and ban use in new equipment after 2005
HCFC-123 ($CHCl_2CF_3$)	0.02	Foams, air-conditioning, fire fighting	EPA likely to approve only air-conditioning use; Clean Air Act bans use in new equipment after 2015
HFC-134a (CH_2FCF_3)	0	Refrigeration, air-conditioning	No restrictions anticipated
HCFC-124 ($CHClFCF_3$)	0.022	Refrigeration, sterilant	Clean Air Act bans use in new equipment after 2015
HFC-125 (CHF_2CF_3)	0	Refrigeration	No restrictions anticipated
HFC-22 (CH_2F_2)	0	Refrigeration, air-conditioning	No restrictions anticipated

[a] Estimates from United Nations Environment Program's "Scientific Assessment of Ozone Depletion: 1991." Estimates depend on chlorine content and atmospheric lifetime. Potentials are set relative to CFC-11, which is assigned a value of 1.0.

Pollution Prevention at Chemical Plants Benefits Environment at Low Cost

■ ***New study shows that minimizing generation of waste at source cuts pollution management costs, may boost output***

Lois R. Ember, C&EN Washington

The message of a just-released study is simple and direct: pollution prevention pays. As the New York City-based environmental research organization Inform describes in its study of 27 organic chemical manufacturing plants, preventing the generation of waste at the source achieves environmental and economic benefits with minimal implementation costs. Costs are surprisingly low because simple low-tech strategies are all that are needed for the most part.

Over the past decade stricter environmental regulations, soaring waste management costs, and ever fewer acceptable disposal sites have combined to get the chemical industry to take waste aversion, or source reduction, steps. As this latest study and Inform's 1985 survey of the same chemical plants clearly demonstrate, preventing the generation of waste results in less pollution and therefore less need to manage waste. It also conserves natural resources, makes the workplace safer, and improves product yield and quality. Add all that up and the bottom line is cost savings.

Originally, Inform surveyed 29 plants, but one no longer exists and another no longer manufactures chemicals. The remaining 27 plants in the current study are representative of the organic chemical industry as a whole except in one instance. Because their plants were profiled in Inform's 1985 study, managers at these facilities may be more aware of the potential of source reduction and, therefore, more likely to have implemented appropriate activities than managers at other U.S. chemical plants.

In the 1985 study, the chemical plants reported only 44 source reduction activities. These typically included changes or refinements to a process, better material handling or equipment maintenance, and/or equipment changes, modifications, or additions. Returning to these same facilities in 1992, Inform documented an additional 137 source reduction initiatives.

Fewer than 15% of the 181 reported source reduction initiatives involved product changes or chemical substitutions (of raw materials producing less waste). However, each time a plant reported a product change, it also reported complete elimination of the targeted waste stream.

"The most exciting finding? Perhaps it's that our research seems to show there is not a limit to source reduction. Even these 27 plants could be making more improvements," says Mark H. Dorfman, assistant director of Inform's chemical hazards prevention program and an author of the new study.

Those 27 facilities reported a total waste reduction of 129 million lb a year, with six reporting reductions of more than 10 million lb a year. In some instances, targeted waste streams have been completely eliminated, and in others reductions of 90% or greater have been achieved. For example, a Ciba-Geigy dye manufacturing plant in Toms River, N.J., eliminated a heavy metals waste stream by shifting the necessary purification steps to an earlier part of the process.

Of course, the reported source reduction programs affected the quantity of hazardous releases reportable under the Toxics Release Inventory. According to Dorfman, "For 1988, without source reduction activities, hazardous releases and transfers at all of the 27 plants surveyed would have been higher by one third."

The cost of achieving waste reduction is low—in a few cases requiring no capital investment. Moreover, in nearly half the cases, investments of less than $100,000 were needed. A majority of companies have recouped their initial investments in six months or less.

Dollars saved yearly as a result of source reduction are substantial, amounting to between $45,000 and $1 million. Only one source reduction activity reported a net cost increase. This occurred at the Aristech (formerly USS Chemicals) plant in Haverhill, Ohio, which makes such products as phenol, acetone, and α-methylstyrene. When Aristech replaced chromium used for corrosion resistance in its cooling water with a newly available nonmetallic substance, its waste treatment costs increased 40 to 50%.

Even including research and development efforts, the time to implement changes is usually short—generally less than six months. In the case of Ciba-Geigy, for example, two months were needed for the process change.

A majority of the plants surveyed report product yield increases. The reason is simple: Efficiency is usually improved and waste is often reduced dramatically.

Facilities with the most successful pollution prevention programs exhibit at least one of three key features. One is a full cost accounting system that incorporates pollution costs and assigns these expenses to individual processes rather than to general plant overhead. Another is employee training and incentive programs that reach top management and production and maintenance workers. "But perhaps the most surprising outcome of our study," says Dorfman, "is the finding that when leadership comes from operation and environmental managers, those plants have significantly more source reduction activities identified and implemented than those plants in which the leadership is not combined."

What motivates managers to set up pollution prevention programs? Ac-

Preventing waste generation at source pays off for organic chemical plants

Company (location)	Number of source reduction activities	Average reduction (%)	Total amount reduced (thousands of lb per year)	Total saved ($ thousands per year)	Total capital investment ($ thousands)	Average payback period (months)	Average yield increase (%)	Implementation time (months)
LARGE PLANTS (> 100 employees)								
Aristech (Ohio)	16	64%(5)	26,929 (6)	$3755 (6)	$ 9,492 (7)	16.0 (4)	na	na
Atlantic (N.J.)	9	33 (1)	350 (1)	na	na	na	8.0%(1)	na
Chevron (Calif.)	5	66 (3)	140 (1)	200 (1)	na	na	na	na
Ciba-Geigy (N.J.)	16	76 (11)	293 (6)	1593 (8)	290 (8)	7.2 (8)	12.4 (6)	6.7 (6)
Dow (Calif.)	5	98 (3)	12,160 (1)	2726 (2)	250 (1)	1.3 (1)		5 (2)
Du Pont (N.J.)	13	62 (4)	39,290 (10)	3755 (5)	11,000 (2)	43.6 (1)	0 (1)	3 (1)
Exxon (N.J.)	9	72 (9)	17,089 (6)	3412 (6)	18,700 (3)	47.9 (3)		60 (1)
Fisher (N.J.)	21	43 (8)	629 (15)	529 (5)	79 (5)	8.8 (4)	28.0 (1)	18 (1)
ICI Americas (Calif.)	7	67 (3)	125 (4)	266 (4)				
IFF (N.J.)	11	30 (10)					7.0 (1)	3.5 (2)
Merck (N.J.)	5	50 (1)	12,963 (4)	1048 (2)	1,000 (1)	12.0 (1)		
Monsanto (Ohio)	13	90 (7)	17,330 (5)	3716 (6)	60 (2)	1.2 (2)	8.2 (2)	5.5 (2)
Morton (Ohio)	na	na	na	na	na	na	na	na
PMC (Ohio)	8	85 (6)	91 (3)	260 (2)	25 (1)	na	5.0 (1)	12 (3)
MEDIUM PLANTS (50–100 employees)								
American Cyanamid (Ohio)	6	94 (5)	806 (5)	220 (3)	800 (5)	1.5 (3)	0 (1)	7.1 (6)
Borden (Calif.)	13	95 (13)	293 (6)	47 (6)	39 (5)	11.9 (4)	0 (4)	0.5 (4)
Def-Tec (Ohio)	2	88 (1)	3 (1)	27 (2)	na	na	na	na
Rhône-Poulenc (N.J.)	7	53 (3)	248 (6)	366 (6)	4,260 (5)	11.5 (4)	1.0 (2)	6.5 (4)
Shell (Calif.)	na	na	na	na	na	na	na	na
Unocal (Calif.)	1	100 (1)	na	na	na	na	na	na
SMALL PLANTS (< 50 employees)								
Bonneau Dye (Ohio)	na	na	na	na	na	na	na	na
Colloids (Calif.)	3	na	na	na	na	na	na	na
Hart Chem/ J. E. Halma (N.J.)	na	na	na	na	na	na	na	na
ICI Resins (Calif.)	3	na	na	na	na	na	na	na
Max Marx (N.J.)	0	na	na	na	na	na	na	na
Perstorp (Ohio)	7	72 (4)	na	40 (1)	na	na	na	na
Scher (N.J.)	1	100 (1)	na	na	na	na	na	na

Note: Plants not included: Fibrec (plant no longer exists) and Frank Enterprises (no longer in manufacturing); numbers in parentheses indicate the number of source reduction activities for which data in that category were available. **na**=not available, no data provided by plants. **Source:** Inform

cording to the findings of the 1992 study, the problems and costs associated with managing waste is a key motivator, followed closely by environmental regulations. These factors are cited by Frank D. Tejera, plant manager of Borden Chemical's Fremont, Calif., plant, as the reason he got into source reduction. Tejera's facility manufactures adhesives used in making plywood and particle board.

The Borden plant has now "achieved 90 to 95% of the reduction we can. We're still making minor changes, tweaking the system, but the payback is starting to get less attractive," Tejera explains.

Still he waxes enthusiastic about source reduction. "It's been successful beyond our wildest expectation. Source reduction pays. What little investment you make you can get back in spades. All it takes is a little creativity, doing your homework, and elbow grease."

Massachusetts was the first state to pass a toxic use reduction law, and its Department of Environmental Protection commissioner, Daniel S. Greenbaum, is rhapsodic about the Inform study. "It is extremely valuable to those of us charged with implementing laws mandating the cutting down of wastes. It will help us [regulators] identify factors that make a difference, that get companies to make a change. And it will help us identify obstacles we're putting in front of companies that want to make a change."

In particular, he believes the study will help regulators detect rules that bar innovation or that keep regulators from looking at a whole facility instead of individual sets of pipes. The report, Greenbaum believes, will also "serve as an independent verification of reductions reported by companies, reports that might otherwise be considered mere boosterism."

Morton L. Mullins, Chemical Manufacturers Association vice president for regulatory affairs, finds the Inform study "balanced, thoughtful—a very useful contribution to the pollution prevention ethic which is clearly evolving in the chemical industry." CMA's Responsible Care guidelines require that member companies institute waste and release reduction programs that emphasize source reduction.

The report, "Environmental Dividends: Cutting More Chemical Wastes," is available from Inform, 381 Park Ave. South, New York, N.Y. 10016, for $75. ☐

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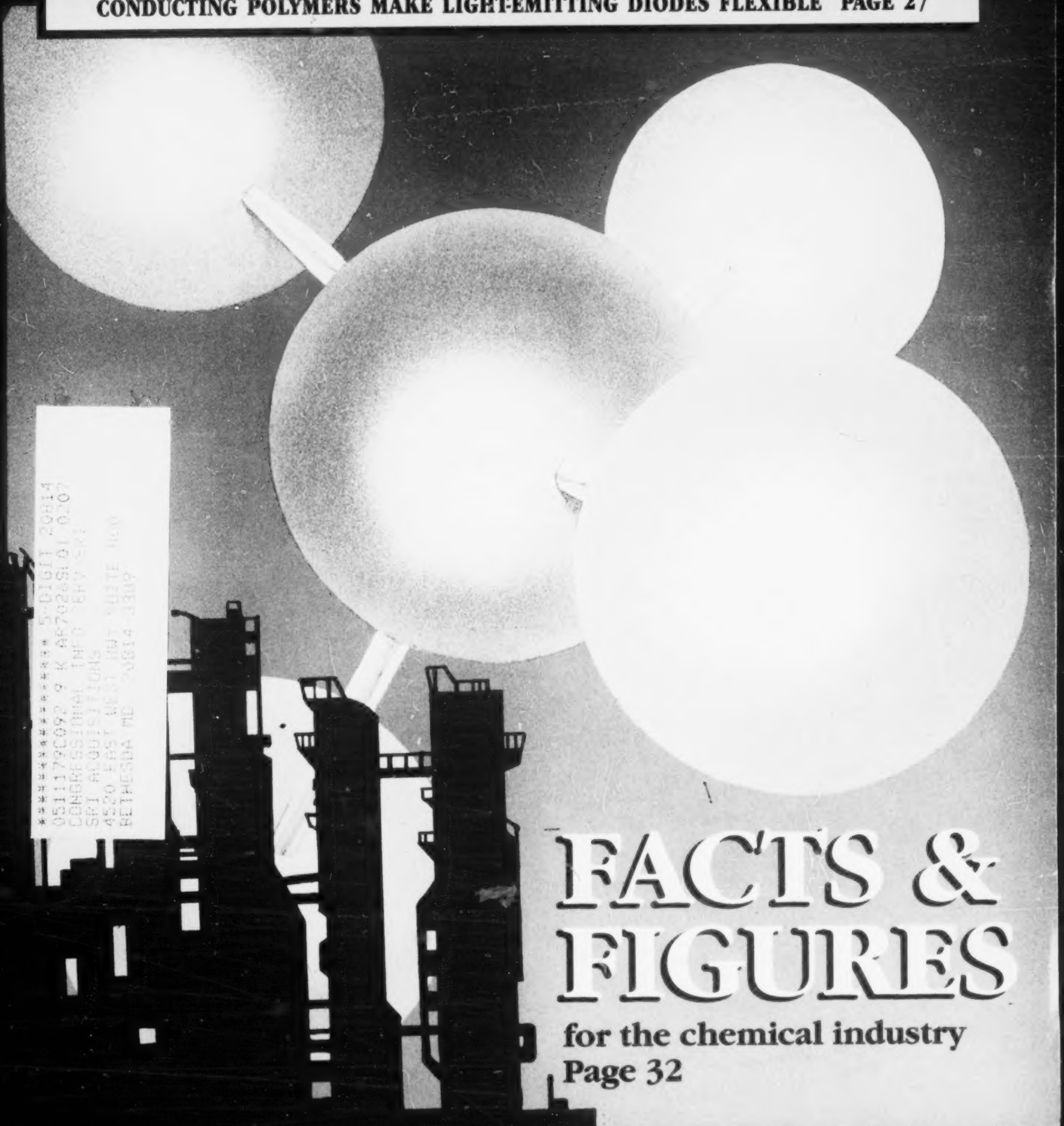
CHEMICAL & ENGINEERING NEWS

C&EN

JUNE 29, 1992

CONDUCTING POLYMERS MAKE LIGHT-EMITTING DIODES FLEXIBLE PAGE 27



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for the chemical industry
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CHEMICAL & ENGINEERING NEWS

C&EN

JUNE 29, 1992

NEWS OF THE WEEK

- Several chemists and Merck & Co. are among the recipients of 1992 National Medals of Science and National Medals of Technology. **Page 6**
- Hercules and Fluor Daniel sign agreement to jointly offer disposal services for explosives, propellants, munitions, and rocket motors, joining several other firms pursuing weapons destruction business. **Page 7**
- New drug, Proscar, developed by Merck for treating enlarged prostate glands in place of surgery, has been approved by FDA for marketing. **Page 7**
- Team of four U.S. students has been chosen to compete in chemistry olympiad in Pittsburgh in July, following recent training camp. **Page 8**
- Fatal lab explosion last winter during cold fusion experiment at SRI International was caused by unexpected buildup of deuterium and oxygen gases in an electrolytic cell. **Page 8**

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BUSINESS

Canadian chemical industry is still trying to recover from recession, despite signs the country's domestic economy is beginning to improve. **Page 11**

GOVERNMENT

Plans to build incinerators for chemical arms destruction may be thwarted because of Army's failure to consider political, social, and regulatory obstacles to such facilities. **Page 19**

U.S. companies must learn to use capital better to improve their competitive position in the global marketplace, according to a study from the Council on Competitiveness. **Page 21**

SCIENCE/TECHNOLOGY

Flexible, light-emitting diode made from conducting polymers is significant development in semiconductor technology. **Page 27**

Studies of catalysis are the focus of R&D efforts in China, especially those related to the processing of heavy crude oils peculiar to that country. **Page 28**

EDUCATION

Hong Kong University of Science & Technology completes its first year, despite controversies about its operating costs and methods of teaching. **Page 31**

BOOKS

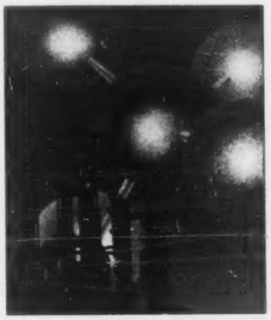
"Scientific Knowledge in Controversy: The Social Dynamics of the Fluoridation Debate" examines the sociological impact of science in the political fights over fluoridation of water. **Page 76**

ACS NEWS

Dale Baker, former director of CAS, has been selected to receive the ACS Board of Directors Distinguished Service Award for Senior ACS Administrators. **Page 79**

ACS membership dues, slated to rise to $93 in 1993, will mean an increase in the allocation from members' dues to C&EN, local sections, and divisions. **Page 80**

FACTS & FIGURES



The recession took its toll on the chemical industry in 1991, but there were some signs by year's end that things may be getting better. C&EN's annual statistical compilation wraps up recent results in the U.S. and abroad. Page 32

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1155—16th St., N.W., Washington, D.C. 20036

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AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

German scientists

In his letter (C&EN, June 8, page 3), Walter Moore is quite correct in stating that very few of the German scientists who did not have Jewish connections resigned and emigrated from Germany during the Nazi period. Among other things, money and positions abroad were limited and quite properly went to those in distress. I believe, however, that he greatly exaggerates the admiration of the senior scientists for Hitler. Max Planck, for one, despised and feared Hitler. Soon after Hitler took office, Planck attempted to convince him he was on the wrong course, but he was viciously rebuffed. The quotation given involving him is out of context.

Samuel Goudsmit, the senior scientist of the ALSOS mission, rescued Planck from desperate circumstances in 1945. Since Goudsmit had lost his parents in one of the extermination camps, he would not have provided such help if he had doubts about Planck's position.

I served in General Eisenhower's headquarters in Frankfurt in 1945 as part of his intelligence office and visited many university administrative offices to look over the official records of the staff. Almost none of those who had been tenured in 1933 were or became party members. After that, it was essentially impossible to receive a faculty appointment unless you were a member, but that is a different matter.

Frederick Seitz
President Emeritus
Rockefeller University
New York City

Drug design

Although Benjamin J. Luberoff certainly makes a number of valid points (C&EN, June 15, page 2) about the ability of a computer to design a drug molecule, his ignoring some of the positive aspects of molecular modeling does a serious disservice to this rapidly growing activity. Most researchers who have done computer-assisted drug design calculations are certainly well aware of the apparent oversimplifications inherent in their modeling, but at the same time they realize that this in itself can yield valuable insights.

A relatively old, but still very significant, example of this can be found in the work by Sid Topiol and colleagues [*J. Chem. Phys.* **68**, 2364 (1978); **70**, 3008 (1979); and later papers] on the binding of various molecular species such as LSD (and other agonists) to 5-HT (serotonin). Despite the fact that the biological reactions being studied occur in complex aqueous in-vivo systems, the electron-density maps constructed on the basis of gas-phase structures correlate surprisingly well with a number of known physiological facts.

This suggests that either the details of complexation with water are relatively unimportant or are somehow incorporated in some of the approximations used. In any event, the results of the calculations are strongly suggestive and certainly promise to further our understanding of some very complex biochemical processes, many of which will probably always remain elusive to the experimentalist.

Of course, Luberoff is entirely correct about finding no mention of any actual contribution to the solution of a commercially significant problem in the article on computer-aided chemistry (C&EN, May 11, page 40). However, many chemists—this writer included—did not enter the field of chemistry to get rich.

Frank L. Pilar
Professor of Chemistry
University of New Hampshire
Durham, N.H.

Cold fusion

In his recent review of "Cold Fusion: The Scientific Fiasco of the Century" by J. F. Huizenga (C&EN, May 25, page 23), Ron Dagani gives considerable space to Huizenga's discussion of a paper by Jack Simons and me, "Two Innocent Chemists Look at Cold Fusion" [*J. Phys. Chem.* **93**, 4693 (1989)]. I've examined the book with some care, and the review properly depicts Huizenga's statements. However, I think these grossly misrepresent both the chronology surrounding the paper and its tenor and purpose and make us look more naive and gullible than we actually were. Since I suspect that the review will

Correction

- June 15, page 1: The cover photo illustrating food additives was courtesy of National Starch & Chemical, not FMC.

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Canada's Chemical Industry Struggles To Recover from Recession

■ ***Although domestic economy seems to be mending, chemical export and production figures are mixed at best***

Like many of its counterparts throughout the world, the Canadian chemical industry is struggling to recover from a recession that has caused sales to fall and profits to plummet. And, like so many of its counterparts, the industry is finding recovery to be a painfully slow process. Witness the following comments from industry leaders.

Alban W. Schuele, president of Celanese Canada, says the short-term outlook does not appear very promising. And, he adds, "there does not seem to be any opportunity at this time for improved earnings."

Speaking of his company's chemicals operations, J. E. (Ted) Newall, president and chief executive officer of Nova Corp. of Alberta, says he expects "much lower losses" in 1992. Still, that spells losses.

Arthur R. Sawchuk, Newall's counterpart at Du Pont Canada, is a bit more optimistic. He believes the fundamentals for an economic recovery in Canada are in place. As a result, he says volumes and prices of chemicals "will slowly strengthen as the year progresses." But even in these remarks, the key word is "slowly."

In Canada, there are, indeed, signs that the domestic economy is inching toward recovery. Employment is up in the manufacturing sector. Productivity is improving. Gross domestic product is gaining. And interest rates have moved noticeably lower.

But the domestic market in Canada is small. For most Canadian chemical companies, exports are critical. This is particularly true of companies that produce large-volume, commodity petrochemicals in world-scale plants.

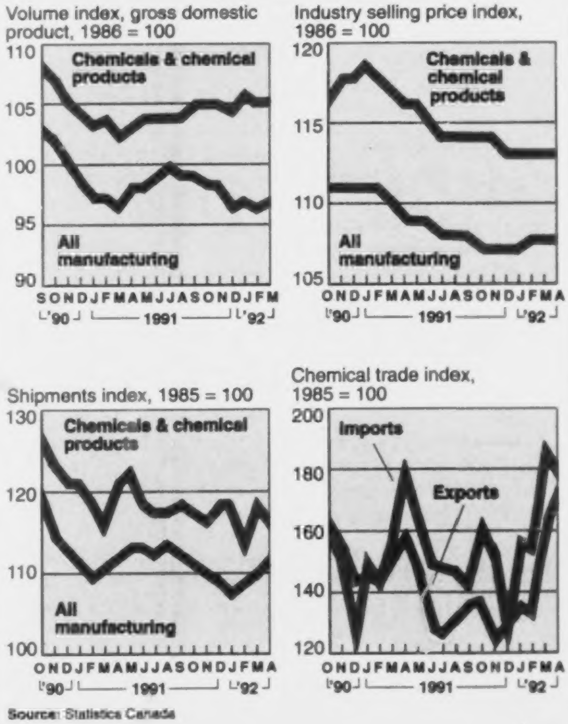
So far this year, exports are flashing mixed signals. Through the first four months, Canadian chemical exports were $2.3 billion at current exchange

Plastics register big gains in output

Production, thousands of metric tons	1991	First four months 1992	First four months 1991	% change 1991–92
INORGANICS				
Ammonia	3669	1255	1208	3.9%
Ammonium nitrate	963	365	340	7.4
Chlorine	1402	481	485	–0.8
Hydrochloric acid	193	62	67	–7.5
Nitric acid	912	320	315	1.6
Sodium chlorate	695	245	240	2.1
Sodium hydroxide	1498	508	526	–3.4
Sulfuric acid	2953	1136	1029	10.4
ORGANICS				
Benzene	712	246	266	–7.5
Ethylene	2425	837	850	–1.5
Formaldehyde	114	42	37	13.5
Methanol	2223	740	772	–4.1
Propylene	717	246	259	–5.0
Toluene	364	134	130	3.1
Urea	2397	896	785	14.1
Xylenes	391	131	164	–20.1
PLASTICS				
Polyesters, unsaturated	33	12	9	33.3
Polyethylene, high density	458	215	127	69.3
Polyethylene, low density	1111	353	399	–11.5
Polystyrene[a]	167	60	59	1.7

[a] Includes ABS (acrylonitrile-butadiene-styrene resins). **Source:** Statistics Canada

Chemical industry growth slips in early '90s



Source: Statistics Canada

rates. That's a paltry 0.4% better than they were during the same period last year and not enough to push production levels upward for most chemical products.

However, chemical exports in March and April, the latest months for which data are available, were strong. In fact, those two figures were higher than they have been for the past two years.

Certainly, exports have given a boost to polyvinyl chloride. Output through the first four months of the year was up a hefty 58%. The domestic market for fabricated PVC products is not that strong. But the export market, primarily to the U.S., has improved dramatically.

Still, overall chemical shipments were essentially flat through April, and the price index has remained stuck in neutral. However, the production index is starting to recover from the lows it reached in March last year.

Chemical production figures present a mixed bag. Polyethylene illustrates this better than anything else. Through the first four months of 1992, output of low-density polyethylene slumped 11.5% from year-earlier levels. Yet, high-density polyethylene production soared 69%. Part of the reason for the discrepancy: Dow Chemical Canada's low-density polyethylene plant in Sarnia, Ontario, was damaged by a fire and was only put back on stream in late April.

The picture is the same throughout the entire spectrum of organic and inorganic chemicals: urea output up 14%, xylenes down 20%; toluene slightly higher, ethylene slightly lower. Among inorganics, sulfuric acid producers have boosted production 10% and ammonia output is almost 4% higher. But chlorine and hydrochloric acid output still are below last year's levels.

If Canada can resolve its constitutional problems and, at the same time, keep its economic recovery on track, its chemical industry likely will mount a sustained recovery drive of its own. But it still is too early for sighs of relief.

Canada's pulp and paper industry, a major outlet for Canadian chemicals, remains in the doldrums. On the other hand, economists expect a slight recovery in construction activity, which bodes well for some chemicals. Faced with this dichotomy of indicators, chemical industry executives are crossing their fingers and hoping for the best.

Earl Anderson

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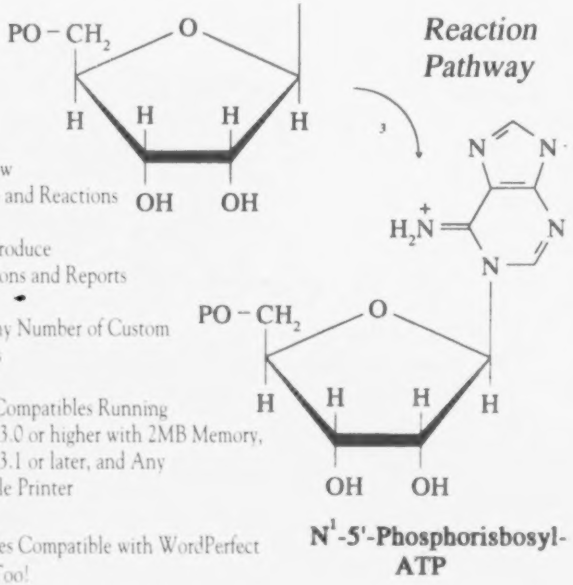

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Army's Plans for Destroying Chemical Weapons Likely To Be Waylaid

■ ***Failure to consider political, social, regulatory obstacles to proposed incinerators may block their construction***

Lois R. Ember, C&EN Washington

Just issued reports and Congressional hearings and bills are conspiring to focus a bright spotlight on the chemical weapons destruction issue. And all this activity is likely to make it more difficult for the Army to carry out its plans to build destruction facilities at eight sites across the U.S.

That plan began to gel in 1984 when, with the endorsement of the National Academy of Sciences, the Army decided that the best way to destroy the U.S. chemical stockpile was to dismantle the munitions and then incinerate the separate parts: chemical agent—nerve or mustard gas—explosives, metal parts, and dunnage (contaminated waste). About four years later, the Army further decided that on-site disposal of chemical weapons at the eight U.S. storage sites would be the safest way to eliminate them. The alternative would have been to transport the weapons to Johnston Atoll in the Pacific Ocean and/or to regional U.S. sites for disposal.

According to Walter L. Busbee, who directs the destruction program, the total stockpile of about 25,000 tons of chemical agents can be destroyed by December 2000 at a cost of nearly $8 billion. What he doesn't say publicly is that mechanical difficulties as well as political, environmental, and legal hurdles are very likely to stretch out the deadline and increase the cost.

Over the years, the Army has focused on incineration, particularly on its technical and economic aspects, and has failed to consider political, social, and regulatory obstacles. Overlooking these barriers and failing to have a backup plan may be the Army's undoing, concludes a just released study by Congress' Office of Technology Assessment.

OTA analyst Mark A. Brown, an author of "Disposal of Chemical Weapons: Alternative Technologies," explains: "The basic issue is one of lack of trust. People just don't trust the Army to have the citizens' best interest at heart and to do a good job to make sure their health and environment are protected."

The Army is now testing full-scale operation of its incineration program on Johnston Atoll. It then wants to export the technology to eight continental U.S. sites.

Brown says the Army has yet to realize that "it doesn't really matter whether [the technology] works or not." For some communities and states that have chemical stockpiles, and for several national and international environmental groups, what matters is "trust and credibility," Brown insists. Both the Army and its chosen technology, incineration, lack these attributes.

The focused, well-organized opposition from citizens, states, and environmental groups could seriously delay, if not prevent, the construction of eight U.S. disposal facilities. So OTA recommends the Army begin now to look at other destruction technologies, and to include early and continuous public participation in decision-making.

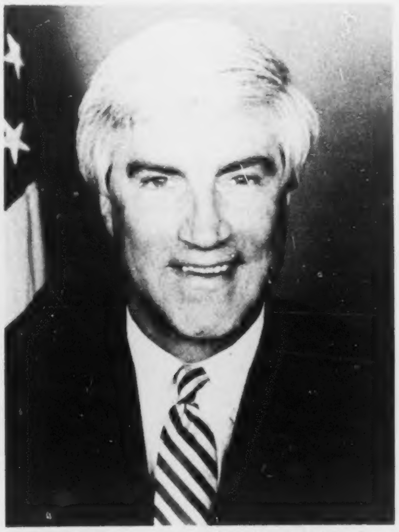
Although Congressional mandates and unratified treaty obligations fix destruction deadlines around the turn of the century, these appear to be flexible constraints. Barring a rapid deterioration of the chemical stockpile, which current data indicate is unlikely, the Army has the time to research, test, and implement an alternative destruction technology.

At the request of Sen. Wendell H. Ford (D.-Ky.), whose state would house one of the disposal facilities, OTA looked at four alternative methods out of a number that have been suggested as possibilities by the environmental group Greenpeace and defense contractors. None of the four—chemical neutralization, supercritical water oxidation, steam gasification, and plasma arc pyrolysis—has been used to destroy chemical weapons. Each is claimed to offer advantages over incineration because each would minimize air emissions and would possibly improve safety during on-site handling and transportation exercises.

Ford: requested look at alternatives

In addition, some groups opposing incineration would also like a technology specific to the destruction of chemical weapons so that it could not be used later to destroy other communities' hazardous waste. And these groups would also like to see the development of an effective community emergency response program.

Unfortunately, there is not enough information for OTA to be able to recommend which of these four alternative methods the Army could adopt for development. Furthermore, the OTA study states, "It is quite possible that if a successful alternative technology is



McMillen: opposes Aberdeen, Md., site

developed for [chemical weapons] destruction, it will be none of these."

Instead, it may be one chosen from a number of alternative disposal methods now being examined by a National Research Council committee. Brown cautions, however, that if the NRC committee considers only technical issues and fails to look at sociopolitical criteria, "then the new technology selected may not offer any advantages over the current technology."

According to NRC staff officer Donald L. Siebenaler, the committee is charged only with looking at "the scientific and technical aspects of the alternatives, not with assessing the political or environmental ramifications of these technologies." Also, he explains, the panel will not select a single alternative technology to incineration, nor will it rank the options.

Still another NRC committee, one which earlier certified the Army's chosen disposal method, has again, in a just released report, concluded that "incineration followed by appropriate gas cleanup is a safe and effective technology for the destruction of chemical agents and munitions." The panel bases its conclusion in part on data collected at the Johnston Atoll facility.

In this latest report, the NRC panel recommends steps that merely fine-tune the incineration system. The panel never considers the possibility that public outcry could prevent the eight other incinerators from being built.

Nor does the Army in its public statements. At a recent hearing by the House Subcommittee on Energy, Environment & Natural Resources, Busbee mentioned that before the Army could build disposal facilities, it had to obtain operating permits under the Resource Conservation & Recovery Act. But he failed to name several other regulatory hurdles.

Busbee did say that "no current or proposed state laws ... prohibit the construction and operation of a chemical weapons destruction plant." But he failed to indicate publicly how restrictive recently passed Kentucky and Indiana laws are that govern such facilities. These laws may make it nearly impossible for the Army to obtain state permits for operating incinerators.

Rep. C. Thomas McMillen (D.-Md.), testifying at the same hearing, said that "Maryland is contemplating enacting similar legislation." McMillen opposes incineration at Aberdeen Proving Grounds in Maryland, because this chemical weapons storage site is in a populated area, and air emissions from the incinerators could adversely affect the nearby Chesapeake Bay.

So opposed is McMillen to the Army's plans that he, along with Rep. Larry J. Hopkins (D.-Ky.), whose district includes the Lexington-Blue Grass storage site, offered an amendment to the 1993 Defense Authorization Bill that would make it nearly impossible for the Army to build incinerators in Maryland, Kentucky, or Indiana. These three states possess the smallest stockpiles, yet have marshalled the most intense state and citizen opposition.

That amendment, approved by the House, changes the current deadline for disposing of the stockpile from 2000 to a date reflecting deadlines in a future treaty banning global chemical weapons. It also creates an independent commission composed of members of the general public as well as technical people to report on alternative disposal options. And it increases the role of public health and safety in the Army's decision-making process.

A similar bill has recently been offered in the Senate by Sen. Ford and Sen. Barbara Mikulski (D.-Md). The Ford-Mikulski bill would also set up an independent advisory commission that would report back to Congress in 1994.

Echoing a key finding of the OTA report, which he commissioned, Ford says, "A disturbing aspect of the current situation regarding the stockpiles is that the Army has no contingency plan in the event Kentucky or another state denies an environmental permit to build an incinerator."

According to Richard A. Davis, General Accounting Office director for Army issues, who also testified before the House hearing, the Army is likely to encounter delays in obtaining environmental permits needed to begin construction of incinerators at Anniston Depot, Ala., and Lexington-Blue Grass, Ky. Because of these delays, GAO recommends deferral of the Army's 1993 funding request totaling $163 million for construction and incineration equipment at these sites.

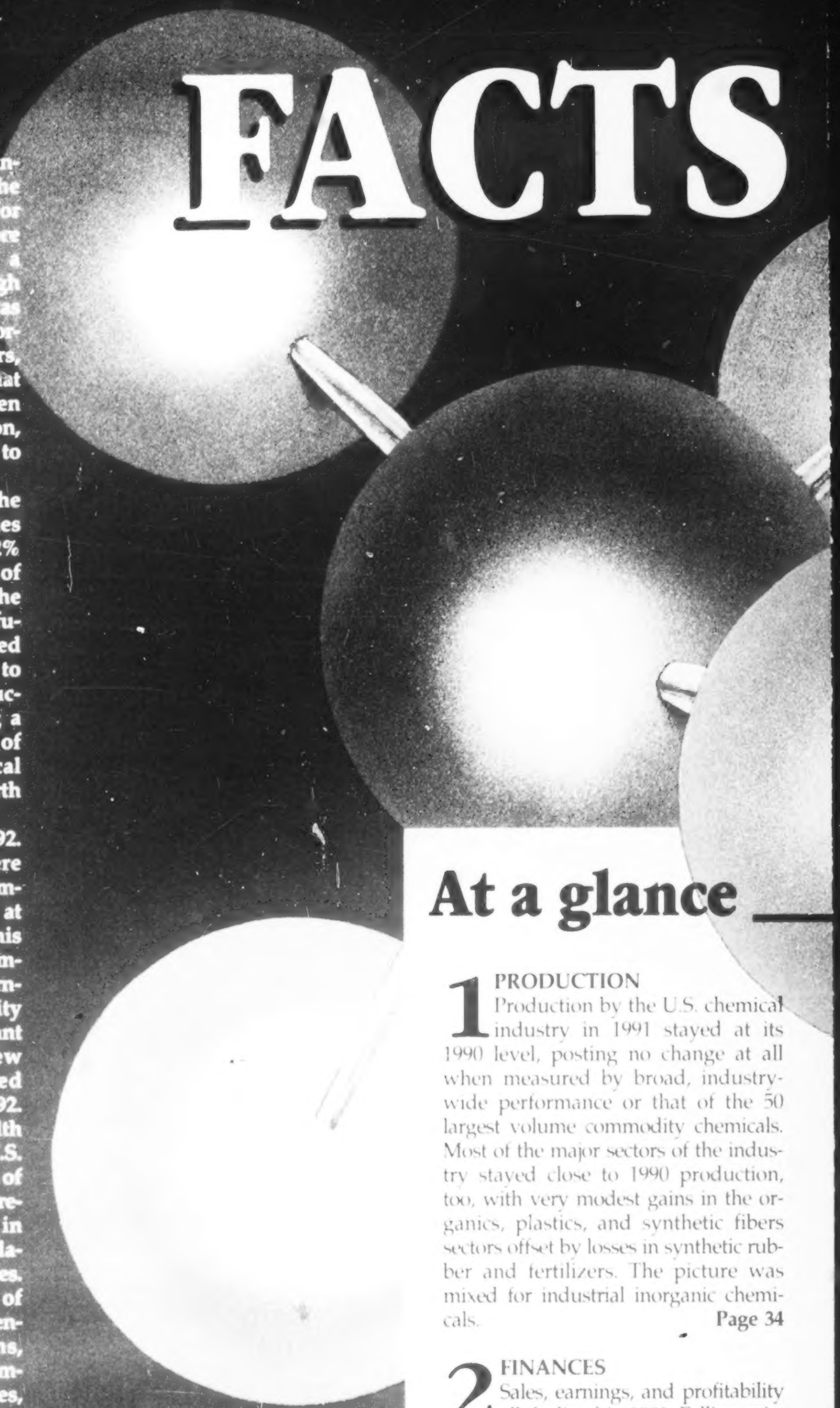
The Senate is expected to mark up the Defense Authorization Bill early next month. The House has passed its version already. ☐

Army plans to destroy chemical stockpile by 2000

Location	% of total U.S. stockpile	Start facility construction	Start testing system	Start operations	End operations
Johnston Atoll (Pacific Ocean)	6.6%	Nov. 1985	Aug. 1988	July 1990	Oct. 1995
Tooele Army Depot (Utah)	42.3	Sept. 1989	Aug. 1993	Feb. 1995	April 2000
Anniston Depot (Ala.)	7.1	June 1993	April 1996	Oct. 1997	Nov. 2000
Umatilla Depot (Ore.)	11.6	Jan. 1994	Nov. 1996	May 1998	Dec. 2000
Pine Bluff Arsenal (Ark.)	12.0	Jan. 1994	Sept. 1996	March 1998	Nov. 2000
Lexington-Blue Grass (Ky.)	1.6	May 1994	March 1997	Sept. 1998	Feb. 2000
Pueblo Depot (Colo.)	9.9	May 1994	March 1997	Sept. 1998	May 2000
Newport Ammo Plant (Ind.)	3.9	Jan. 1995	June 1997	June 1998	April 1999
Aberdeen Proving Ground (Md.)	5.0	Jan. 1995	June 1997	June 1998	June 1999

Note: This schedule does not take into account delays from major system failures or litigation and is dependent on funding support. **Source:** Army

FACTS



Recession hit the chemical industry in 1991 as it did the rest of the economy; but for chemicals, at least, it seemed more like a lingering head cold than a full-fledged bout of the flu. Though there's no doubt that last year was the second in a row of poor performance for U.S. chemical makers, there were signs by year's end that the worst might be over. If so, then the industry's most recent recession, though dragging on, may turn out to have been a relatively mild one.

Earnings fell 16% in 1991 for the group of key chemical companies that C&EN tracks, following a 22% drop the previous year. This loss of revenue began to take its toll in the industry's ability to invest in its future, as capital spending declined and even R&D funding failed to keep pace with inflation. Production leveled off last year, ending a decade of steady gains, as some of the biggest markets for chemical output posted their third or fourth year of poor performance.

But things may be better in 1992. Though sales and earnings were down for the first quarter for chemical makers as a group, big losses at one company probably distort this picture. Most major chemical companies saw increases in sales, earnings, production, and profitability for the quarter. And some important chemical markets, notably new housing starts, had also turned around in the early months of 1992.

A more detailed look at the health of the chemical industry in the U.S. and, to a lesser extent, in the rest of the chemical-producing world is presented on the following pages in C&EN's annual statistical compilation of the relevant facts and figures. These data come from a variety of sources, including government agencies, international organizations, trade associations, and chemical companies themselves. In some cases, C&EN has pulled together raw data from several sources to develop analytical measures that bring the industry's performance into sharper focus.

At a glance

1 PRODUCTION

Production by the U.S. chemical industry in 1991 stayed at its 1990 level, posting no change at all when measured by broad, industry-wide performance or that of the 50 largest volume commodity chemicals. Most of the major sectors of the industry stayed close to 1990 production, too, with very modest gains in the organics, plastics, and synthetic fibers sectors offset by losses in synthetic rubber and fertilizers. The picture was mixed for industrial inorganic chemicals.

Page 34

2 FINANCES

Sales, earnings, and profitability all declined in 1991. Falling prices led to a 1% drop in sales for the 30 chemical companies C&EN surveys

& FIGURES

for the chemical industry

regularly, and whose output leans heavily toward industrial chemicals. As a group, their profits fell 16% to a four-year low of $4.47 billion. Specialty chemical makers and drug companies did somewhat better. Capital spending at chemical firms also fell 16% last year, and these firms' modest increases in R&D spending failed to keep pace with inflation. **Page 41**

3 EMPLOYMENT

Chemical industry employment reached a peak of 1.09 million people early in 1990 and eased downward for the remainder of that year. It's been holding steady at about 1.07 million since March 1991. Among the larger chemical companies, employment fell 3% in 1991, following a 2% decline in 1990. At the same time, hourly production wages rose, so that productivity gains brought about by a smaller work force were largely offset by higher labor costs. **Page 55**

4 MARKETS

Major markets for chemicals generally did poorly in 1991, reflecting the broader trends of the U.S. economy. Some of the most important markets, including new housing and automobiles, fared worse than consumer spending generally in what was only the most recent in a string of poor years. **Page 60**

5 FOREIGN TRADE

The U.S. chemical trade surplus reached an all-time high of $18.8 billion in 1991, making that the sixth year in a row of record-setting trade surpluses. Trade was strong to all parts of the world except the formerly communist countries of Eastern Europe, as U.S. chemical exports jumped 10%. Imports were up 8%. **Page 62**

6 FOREIGN CHEMICAL INDUSTRIES

Downturn characterized the chemical industries throughout the industrialized world in 1991. Although chemical makers in Germany, France, and the U.K. increased sales by 3% last year, most had declines in earnings; and chemical companies in the rest of Western Europe, in Japan, and in Canada generally saw sales and earnings fall. In Eastern Europe, chemical production, like industrial production generally, fell sharply last year for the second year in a row. **Page 64**

1 PRODUCTION BY THE U.S. CHEMICAL INDUSTRY

Chemical production held steady in 1991

At first glance, production by the U.S. chemical industry in 1991 continued at the same steady levels of 1990. According to data for the year as a whole from the Federal Reserve Board, production of chemicals and allied products didn't change at all in 1991. Production of the largest volume chemicals, C&EN's Top 50, was similarly stagnant for the year.

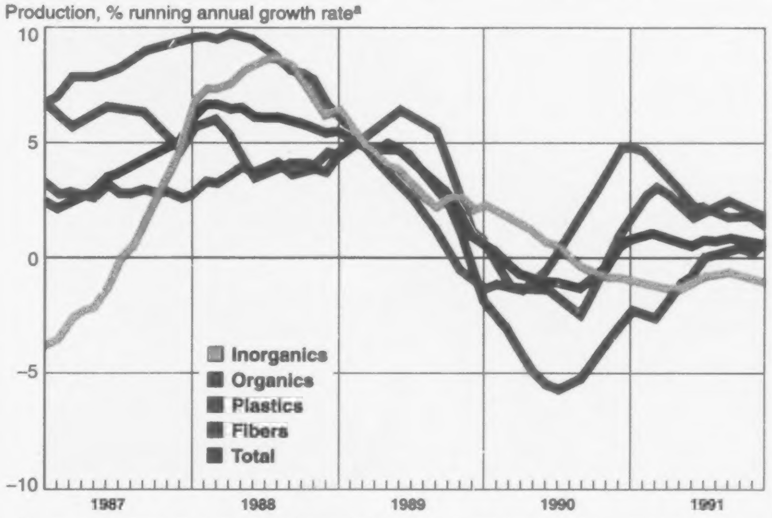
Month-to-month data, however, show the beginnings of recovery toward the end of 1991 and continuing, so far, into 1992. The last three months of 1991 each posted a 3% increase in production over the same month a year earlier, according to Federal Reserve Board data. The early months of 1992 show stronger improvement, with February, March, and April registering 4%, 5%, and 6% gains, respectively, over year-earlier levels.

Thus, by the end of 1991, there were hopeful signs that the long, but relatively mild, recession that had held chemical production levels flat for two years was finally coming to an end.

As was true for chemical output overall for 1991, annual production for major segments of the chemical industry was generally sluggish. Basic chemicals, a subcategory that includes chlor-alkalies, industrial gases, and other industrial inorganic chemicals, gained 3% for the year, according to the Federal Reserve Board. Production of inorganics in C&EN's Top 50 actually fell 1% for the year, but for organic chemicals in the Top 50, output increased a modest 2%.

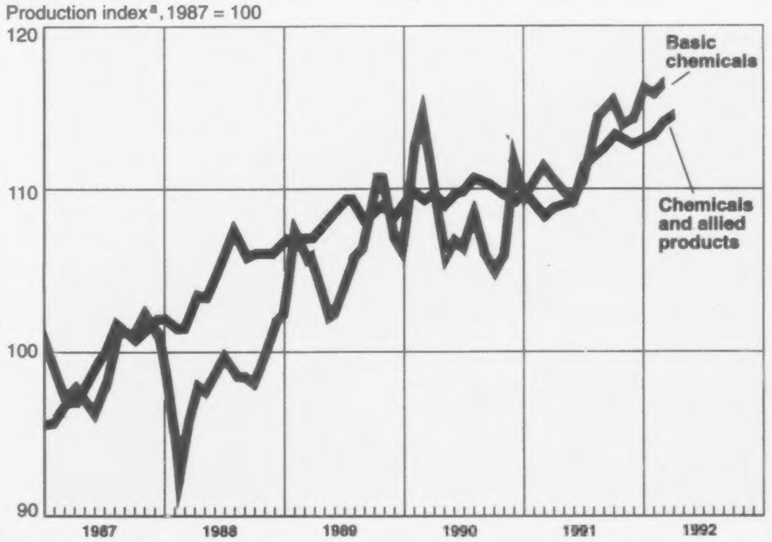
Plastics output rose 3% in 1991, well below 1990's 8% gain and trailing its average annual gain of 5% over the past 10 years. Synthetic fibers posted a 1% gain for the year, thanks mostly to a partial recovery in the polyester fiber market, following a particularly bad showing in 1990. Synthetic rubber production did poorly in 1991, dropping 4% from 1990, making 1991 the third consecutive year of declining production. Fertilizer use slipped 2% in the 1991 crop year, which ended last June.

Output growth dampened for all chemical sectors



[a] Average running annual growth rates in production of major plastics, inorganic and organic chemicals, and all chemicals, and in shipments of man-made fibers. **Sources:** International Trade Commission, Bureau of the Census, Society of the Plastics Industry, Textile Economics Bureau

Chemical production resumed growth late last year



[a] Seasonally adjusted. **Source:** Federal Reserve Board

TOP 50 CHEMICALS: Output was 633 billion lb last year, barely budging from 1990

Rank 1991	Rank 1990[a]		Billions of lb 1991	Billions of lb 1990
1	1	**Sulfuric acid**	86.62	88.09
2	2	**Nitrogen**	57.03	56.23
3	4	**Ethylene**	39.23	36.47
4	3	**Oxygen**	38.99	40.48
5	6	**Ammonia**	34.04	33.59
6	5	**Lime**[b]	33.60	34.90
7	7	**Phosphoric acid**	24.68	24.07
8	8	**Sodium hydroxide**	24.39	24.06
9	9	**Chlorine**	22.65	23.62
10	10	**Propylene**	22.02	21.85
11	11	**Sodium carbonate**[c]	20.50	20.18
12	12	**Urea**[d]	16.14	16.24
13	13	**Nitric acid**	15.05	16.00
14	14	**Ammonium nitrate**[e]	14.62	14.16
15	15	**Ethylene dichloride**	13.92	13.85
16	16	**Benzene**	11.78	12.45
17	17	**Vinyl chloride**	11.70	10.63
18	18	**Carbon dioxide**[f]	9.76	10.37
19	19	**Methyl *tert*-butyl ether**	9.60	8.89
20	20	**Ethylbenzene**	9.22	8.37
21	22	**Styrene**	9.01	8.02
22	21	**Methanol**	8.65	8.35
23	23	**Terephthalic acid**[g]	7.66	7.77
24	25	**Toluene**[h]	6.80	6.21
25	24	**Formaldehyde**[i]	6.43	6.72
26	25	**Xylene**[j]	6.13	6.21
27	27	**Hydrochloric acid**	5.60	6.03
28	29	***p*-Xylene**	5.43	5.20
29	28	**Ethylene oxide**	5.24	5.36
30	31	**Ethylene glycol**	4.93	5.07
31	30	**Ammonium sulfate**	4.46	5.08
32	32	**Cumene**	4.28	4.31
33	33	**Potash**[k]	3.90	3.78
34	34	**Acetic acid**	3.61	3.75
35	35	**Phenol**[l]	3.49	3.54
36	36	**Butadiene**[m]	2.91	3.09
37	40	**Propylene oxide**	2.75	2.60
38	37	**Carbon black**	2.72	2.87
39	38	**Acrylonitrile**	2.65	2.68
39	39	**Vinyl acetate**	2.65	2.66
41	42	**Aluminum sulfate**	2.36	2.45
42	41	**Cyclohexane**	2.31	2.46
43	44	**Titanium dioxide**	2.19	2.15
44	43	**Acetone**	2.13	2.33
45	45	**Sodium silicate**	1.79	1.76
46	46	**Adipic acid**	1.56	1.62
47	47	**Sodium sulfate**[n]	1.54	1.57
48	48	**Isopropyl alcohol**	1.30	1.38
49	50	**Calcium chloride**[o]	1.29	1.38
50	49	**Caprolactam**	1.28	1.38
		TOTAL ORGANICS	**224.82**	**219.45**
		TOTAL INORGANICS	**407.77**	**412.82**
		GRAND TOTAL	**632.59**	**632.27**

a Revised. **b** Except refractory dolomite. **c** Natural and synthetic. **d** 100% basis. **e** Original solution. **f** Liquid and solid only. **g** Includes both acid and ester without double counting. **h** All grades. **i** 37% by weight. **j** Mixed, all uses. **k** K_2O basis. **l** Synthetic only. **m** Rubber grade. **n** High and low purity. **o** 75% basis, solid and liquid.

PRODUCTION: Slight increases for some chemicals amid declines in manufacturing overall

Industrial production indexes, 1987 = 100	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	% annual change 1990–91	% annual change 1981–91
Total index	107.1	109.2	108.1	105.4	100.0	95.3	94.4	92.8	84.9	81.9	85.7	–2%	2%
Manufacturing, total	107.4	109.9	108.9	105.8	100.0	94.3	91.6	89.3	80.9	76.6	80.3	–3	3
Nondurable manufacturing	107.9	107.8	106.4	103.6	100.0	94.9	91.5	90.8	87.0	82.5	84.5	0	3
Chemicals and products	110.9	110.3	108.5	105.4	100.0	94.6	91.4	91.4	87.5	81.8	89.2	0	2
Chemicals and synthetic materials	106.8	107.2	106.5	102.5	100.0	93.9	92.2	92.8	88.6	79.4	91.2	0	2
Basic chemicals	111.9	108.6	106.6	98.3	100.0	95.1	96.1	96.9	92.1	86.5	96.9	3	2
Alkalies and chlorine	96.3	99.5	103.2	96.0	100.0	92.1	93.6	95.3	87.9	82.1	94.6	–3	0
Industrial gases	111.9	109.2	108.0	104.1	100.0	98.8	92.8	97.5	85.9	80.1	91.2	2	2
Inorganic pigments	103.9	104.3	111.0	102.6	100.0	96.2	95.1	89.0	87.3	79.1	90.7	0	1
Inorganic chemicals, nec	115.0	110.1	105.7	96.4	100.0	94.7	97.2	98.0	94.3	89.2	98.7	4	2
Industrial organic chemicals	na	107.1	109.2	103.1	100.0	95.1	94.1	93.4	89.9	81.0	97.0	na	na
Synthetic materials	108.5	106.5	103.1	104.4	100.0	91.6	86.9	88.9	84.3	71.8	79.5	2	3
Plastics materials	120.0	115.8	106.7	106.8	100.0	88.2	84.1	81.1	74.4	64.4	68.3	4	6
Synthetic rubber	84.1	88.6	92.4	105.0	100.0	109.3	114.4	132.8	124.1	110.5	114.5	–5	–3
Man-made fibers	92.0	92.7	98.7	99.5	100.0	93.7	86.6	93.3	92.3	76.4	91.7	–1	0
Chemical products	114.7	113.3	110.1	107.5	100.0	95.9	90.2	89.0	86.6	83.0	85.4	1	3
Drugs and medicines	122.0	114.0	108.1	107.2	100.0	96.7	88.5	86.9	86.1	82.7	80.9	7	4
Soaps and toiletries	107.6	112.3	111.1	107.9	100.0	96.7	91.3	90.6	91.4	89.2	97.7	–4	0
Paints	90.0	99.5	104.8	103.9	100.0	97.5	95.7	91.8	84.6	78.8	84.1	–9	1
Agricultural chemicals	105.3	105.1	108.2	107.2	100.0	88.5	96.1	102.0	87.5	88.8	102.3	0	0
Petroleum products	107.5	108.2	106.1	103.4	100.0	98.9	92.6	92.8	89.6	89.3	94.1	–1	1
Rubber and plastics products	110.0	110.2	108.9	105.9	100.0	90.8	85.8	83.8	74.3	65.9	66.6	0	5

na = not available. **nec** = not elsewhere classified. **Source:** Federal Reserve Board

1

PRODUCTION BY THE U.S. CHEMICAL INDUSTRY

ORGANIC CHEMICALS: Ethylene, vinyl chloride post gains amid general downturn

Millions of lb unless otherwise noted	Production											% annual change	
	1991[a]	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1990–91	1981–91
Acetic acid, synthetic	3,612	3,751	3,294	3,159	3,246	2,728	2,897	2,619	2,807	2,748	2,705	–4%	3%
Acetone	2,130	2,329	2,524	2,303	1,846	1,910	1,788	1,862	1,859	1,694	2,144	–9	0
Acrylonitrile	2,647	2,676	2,609	2,452	2,182	2,349	2,219	2,146	2,035	1,997	–1	–1	3
Aniline	996	989	1,016	1,029	829	824	716	786	663	557	634	1	5
Benzene, mg[b,c]	1,605	1,699	1,631	1,608	1,575	1,362	1,283	1,318	1,232	1,052	1,308	–6	2
Bisphenol A	1,181	1,149	1,241	1,340	1,000	956	949	762	643	480	555	3	8
1,3-Butadiene[d]	2,912	3,088	3,121	3,169	2,931	2,546	2,340	2,452	2,353	1,915	2,986	–6	0
1-Butanol	1,314	1,269	1,751	1,194	1,155	881	716	908	833	730	809	4	5
Caprolactam	1,284	1,379	1,307	1,261	1,156	1,109	1,089	1,027	977	793	928	–7	3
Carbon tetrachloride	na	413	na	761	672	627	646	713	573	587	726	—	—
Chloroform	na	484	588	524	462	422	275	405	362	299	405	—	—
Cumene	4,284	4,311	4,426	4,455	4,105	3,745	2,627	3,754	3,345	2,743	3,309	–1	3
Cyclohexane	2,308	2,460	2,273	2,297	2,276	2,070	1,657	1,994	1,656	1,275	1,820	–6	2
Dioctyl phthalate	na	310	306	344	343	296	275	301	300	266	304	—	—
Ethanol, synthetic	na	546	549	562	574	529	649	1,060	1,077	1,023	1,317	—	—
Ethanolamines[e]	642	727	667	608	627	543	537	504	468	416	429	–12	4
Ethylbenzene	9,219	8,369	9,235	9,929	9,346	9,020	7,386	7,562	7,876	6,656	7,813	10	2
Ethyl chloride	na	149	162	152	155	164	171	290	282	339	324	—	—
Ethylene	39,224	36,467	34,988	37,204	34,951	32,859	29,847	31,383	28,680	24,501	29,418	8	3
Ethylene dichloride	13,919	13,849	13,383	13,028	12,197	12,940	12,101	10,710	11,506	7,619	9,974	1	3
Ethylene glycol	4,930	5,070	5,461	5,517	5,183	4,771	4,178	4,823	4,425	4,309	4,143	–3	2
Ethylene oxide	5,243	5,355	5,031	5,953	4,785	5,430	5,430	5,699	5,534	4,987	4,937	–2	1
2-Ethylhexanol	641	650	612	743	662	571	536	541	387	325	389	–1	5
Formaldehyde, 37%[f]	6,424	6,720	5,893	6,280	5,733	5,549	5,606	5,815	5,465	4,817	5,721	–4	1
Isobutylene	1,104	1,212	1,193	1,244	1,035	1,124	na	883	760	741	1,035	–9	1
Isopropyl alcohol	1,296	1,456	1,474	1,389	1,371	1,301	1,235	1,394	1,209	1,380	1,669	–11	–2
Maleic anhydride	382	424	475	448	382	359	394	359	299	260	293	–10	3
Methanol, synthetic	8,654	8,344	8,167	8,142	7,537	7,205	5,003	8,186	7,982	7,555	8,577	4	0
Methyl *tert*-butyl ether	9,600[g]	8,884	8,227	5,680	3,514	3,375	1,891	1,376	839	824	760	8	29
Methyl chloride	784	772	461	597	373	605	410	482	409	366	405	2	7
Methyl ethyl ketone	523	465	450	482	672	600	537	543	531	468	614	12	–2
Methyl methacrylate	1,102	1,182	1,161	1,100	1,029	943	858	917	844	721	592	–7	6
Methylchloroform	649	803	783	724	694	652	869	675	586	595	611	–19	1
Methylene chloride	389	461	482	504	516	566	467	607	584	532	891	–16	–8
Perchloroethylene	240	372	481	498	473	414	678	573	547	585	691	–35	–10
Phenol, synthetic[h]	3,484	3,538	3,806	3,562	3,351	3,115	2,841	2,889	2,638	2,023	2,578	–2	3
Phthalic anhydride	874	940	917	999	1,035	863	820	870	838	684	870	–7	0
Propylene[i]	22,019	21,846	20,571	21,224	19,019	16,522	14,887	15,559	13,959	12,535	13,482	1	5
Propylene glycol	745	754	805	840	747	573	500	462	484	400	473	–2	5
Styrene	9,003	8,017	8,337	8,984	8,014	7,888	7,622	7,709	6,802	5,942	6,679	12	3
Terephthalic acid, dimethyl ester[j]	7,654	7,773	8,426	10,234	7,601	6,257	6,490	5,912	5,626	4,843	6,235	–2	2
Toluene, mg[b,k]	940	861	806	892	967	611	698	728	780	714	852	9	1
Vinyl acetate	2,645	2,659	2,552	2,561	1,813	1,710	2,112	2,024	1,963	1,876	1,936	–1	3
Vinyl chloride	11,694	10,623	10,135	9,058	8,402	8,439	9,463	6,084	6,875	4,902	6,874	10	5
***o*-Xylene**	935	943	983	971	940	788	675	688	781	802	918	–1	0
***p*-Xylene**	5,432	5,200	5,344	5,601	5,155	5,035	4,779	4,264	4,114	3,391	4,532	4	2

Note: mg = millions of gallons. **a** Preliminary. **b** Tar distillers and coke-oven operators not included. **c** Specification grades. **d** Rubber grade. **e** Mono-, di-, and triethanolamines. **f** By weight. **g** C&EN estimate. **h** Does not include data for coke ovens and gas-retort ovens. **i** All grades. **j** Includes both acid and dimethyl ester (DMT), without double counting. **k** High-purity toluene, includes material used in blending motor fuel. **na** = not available. **Source:** International Trade Commission

INORGANIC CHEMICALS: Mixed picture includes more declines than increases

Thousands of tons unless otherwise noted	Production											% annual change	
	1991[a]	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1990–91	1981–91
Aluminum sulfate[b]	1,180	1,227	1,243	1,237	1,227	1,222	1,268	1,129	1,119	1,154	1,294	–4%	–1%
Ammonia, 100%[c,d]	17,020	16,796	16,468	16,821	16,098	14,487	17,319	16,692	14,072	15,801	19,044	1	–1
Ammonium nitrate, 100%[e]	7,310	7,081	7,871	7,504	6,547	6,091	7,149	7,146	6,240	7,091	8,861	3	–2
Ammonium sulfate, 100%[d,f]	2,230	2,539	2,384	2,333	2,189	2,080	2,093	2,067	1,956	1,768	2,185	–12	0
Chlorine gas[g]	11,324	11,810	11,413	11,257	11,078	10,436	10,402	10,700	9,960	9,176	10,763	–4	1
Hydrochloric acid, 100%[h]	2,799	3,013	3,268	3,228	2,996	2,413	2,807	2,732	2,468	2,450	2,574	–7	1
Hydrogen, bcf, 100%[i,j]	142	148	146	177	173	136	121	109	103	88	105	–4	3
Hydrogen peroxide, 100%[k]	263	238	204	168	153	152	144	139	117	108	111	11	9
Nitric acid, 100%[k]	7,524	7,999	8,349	7,991	7,225	6,734	7,631	7,726	6,768	7,390	9,093	–6	–2
Nitrogen gas, bcf, 100%[i,l]	787	749	744	722	685	677	665	661	560	483	490	5	5
Oxygen, bcf, 100%[i,l]	471	462	460	452	405	383	393	375	346	349	431	2	1
Phosphoric acid, 100% P_2O_5	12,342	12,034	11,737	11,659	10,599	9,578	10,607	11,370	9,767	8,253	9,958	3	2
Phosphorus[m]	312	346	353	343	344	364	359	386	366	361	426	–10	–3
Sodium chlorate, 100%	457	317	290	267	289	267	259	295	323	291	297	44	4
Sodium hydroxide, 100%	12,197	12,030	11,470	10,533	11,553	10,691	10,811	10,914	10,039	9,385	10,621	1	1
Sodium phosphate[n]	445	496	610[o]	549	586	617	625	675	669	651	696	–10	–4
Sodium silicate[p]	894	816	833	812	952	791	692	685	710	664	771	10	2
Sodium sulfate, 100%[q]	767	786	755	819	799	837	1,203	901	914	864	1,111	–2	–4
Sulfuric acid, 100%[r]	43,308	44,044	43,301	42,580	39,256	35,993	39,890	41,802	36,583	33,233	40,742	–2	1
Titanium dioxide, 100%[s]	1,093	1,077	1,101	1,022	968	931	860	835	760	660	761	1	4
Urea	8,072	8,120	8,004	7,914	7,433	6,264	6,975	7,433	6,137	6,470	8,062	–1	0

Note: bcf = billions of cubic feet. **a** Preliminary. **b** Commercial, 17% Al_2O_3; includes municipalities. **c** Synthetic anhydrous. **d** Excludes by-product ammonia liquor and ammonium sulfate. **e** Original solution. **f** Synthetic and noncoke by-product. **g** Includes quantities liquefied for use, storage, or shipment. **h** Includes anhydrous hydrochloric acid production. **i** High- and low-purity gas. **j** Liquid and gas; excludes amounts vented and used as fuel, and amounts produced in petroleum refineries for captive use. **k** Includes unspecified amounts produced but not withdrawn from the system. **l** Excludes amounts produced and consumed in making synthetic ammonia or ammonia derivatives. **m** Elemental, white (yellow), and red. **n** Tripolyphosphate (100% $Na_5P_3O_{10}$). **o** Includes tetrabasic (pyro) phosphate. **p** Soluble silicate glass (water glass), solid and liquid (anhydrous); excludes amounts produced and consumed in making meta-, ortho-, and sesquisilicates. **q** Anhydrous, high and low purity, and Glauber's salt. **r** Gross (new and fortified). **s** Composite and pure. **Sources:** Department of Commerce, International Trade Commission

MINERALS: For most minerals, 1991 was second year of declining production

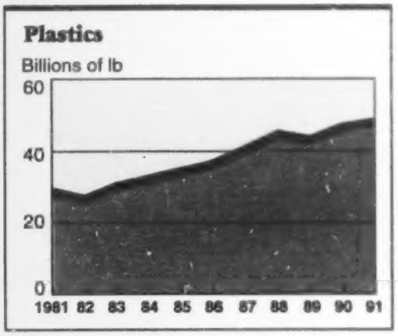
Thousands of tons	1991[a]	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	% annual change 1990–91	% annual change 1981–91
Bromine, sold or used[b]	187	195	193	180	168	155	160	193	185	200	189	–4%	0%
Calcium chloride, production[c]	644[d]	690[d]	801[d]	731	658	780	940	1,036	912	853	917	–7	–3
Lime, production[e]	16,800[d]	17,452	17,152	17,052	15,733	14,474	15,690	15,922	14,867	14,075	18,890	–4	–1
Lithium, consumption[d,f]	2.9	3.0	3.0	3.0	2.6	2.6	2.5	3.2	2.2	2.0	3.2	–3	–1
Phosphate rock													
Production	53,016	51,084	54,913	50,032	45,144	44,445	56,035	54,230	46,928	41,241	59,110	4	–1
Exports	5,768	6,876	8,644	8,920	9,319	8,651	10,071	12,707	13,239	10,849	11,458	–16	–7
Potash (K_2O equivalent)[g]													
Production	1,951[d]	1,888	1,758	1,677	1,391	1,325	1,429	1,724	1,575	1,967	2,377	3	–2
Imports	4,630[d]	4,590	3,758	4,648	4,490	4,643	5,063	5,323	4,894	4,253	5,287	1	–1
Apparent consumption[h]	5,890[d]	6,011	4,960	5,803	5,609	5,338	5,893	6,638	6,231	5,647	6,849	–2	–2
Sodium carbonate, production[i]	9,926	10,093	9,915	9,632	8,891	8,438	8,511	8,511	8,467	7,819	8,281	–2	2
Sulfur, production[j]	11,847	12,743	12,778	11,845	11,616	12,221	12,797	11,742	10,240	10,788	13,388	–7	–1
Recovered elemental	7,362	7,205	7,176	7,103	6,791	6,411	5,857	5,747	5,462	4,855	4,695	2	5
Frasch	3,162	4,107	4,286	3,499	3,530	4,457	5,524	4,622	3,530	4,641	6,997	–23	–3
Other production	1,323[d]	1,431	1,316	1,243	1,296	1,354	1,416	1,372	1,249	1,293	1,695	–7	–2
Apparent consumption[h]	13,669	14,392	13,983	14,012	12,481	11,669	13,192	13,976	12,112	11,088	14,093	–5	0

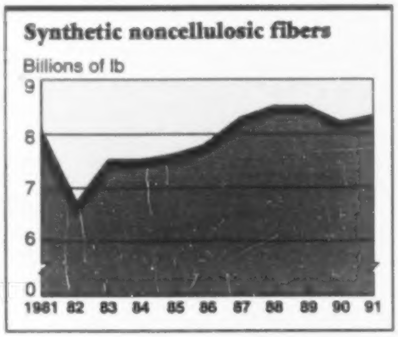
a Preliminary data, except those for phosphate rock. **b** Elemental bromine sold as such or used in preparation of bromine compounds by primary producers. **c** 75% $CaCl_2$ equivalent. **d** Estimated. **e** Sold or used by producers for commercial or captive use. Produced from limestone and dolomite, does not include amount regenerated by paper industry; excludes Puerto Rican production. **f** Lithium content basis. **g** Includes muriate and sulfate of potash, potassium magnesium sulfate, and parent salts; excludes other chemical compounds containing potassium. **h** Calculated from shipments plus imports minus exports. **i** Natural and synthetic for 1980–86, natural only in 1987–90. **j** Sulfur content basis. **Sources:** Bureau of Mines, Bureau of the Census

PLASTICS: Increases for major thermoplastics buoyed resin production last year

	Production											% annual change	
Millions of lb[a]	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1990–91	1981–91
THERMOSETTING RESINS													
Epoxy[b]	531	499	509	486	433	398	385	406	334	286	336	6%	5%
Melamine	196	202	222	207	212	173	192	210	180	158	179	–3	1
Phenolic[c,d]	2,658	2,946	2,879	3,066	2,869	2,735	2,621	2,502	2,477	2,006	2,333	–10	1
Polyester[e]	1,075	1,221	1,319	1,404	1,367	1,271	1,223	1,232	1,084	865	997	–12	1
Urea	1,483	1,496	1,477	1,425	1,382	1,271	1,210	1,199	1,172	998	1,165	–1	2
TOTAL	**5,943**	**6,364**	**6,408**	**6,588**	**6,263**	**5,848**	**5,631**	**5,549**	**5,247**	**4,313**	**5,010**	**–7**	**2**
THERMOPLASTIC RESINS													
Polyethylene													
Low density[f]	11,580	11,148	9,695	10,397	9,599	8,903	8,889	8,413	8,041	7,503	7,693	4	4
High density[g]	9,216	8,337	8,102	8,400	7,995	7,182	6,671	6,085	5,689	4,928	4,695	11	7
Polypropylene	8,335	8,310	7,238	7,274	6,647	5,812	5,139	4,940	4,433	3,477	3,955	0	8
Styrene polymers													
Polystyrene	4,956	5,021	5,104	5,187	4,780	4,470	4,054	3,838	3,570	3,191	3,621	–1	3
Styrene-acrylonitrile	109	135	113	148	126	92	87	99	93	91	107	–19	0
Acrylonitrile-butadiene-styrene and other styrene polymers[h]	2,289	2,351	2,394	2,418	2,254	2,196	2,036	2,127	1,889	1,380	1,745	–3	3
Polyamide, nylon type	576	558	569	566	507	465	399	396	321	228	312	3	6
Vinyl resins													
Polyvinyl chloride and copolymers	9,168	9,096	8,478	8,350	7,971	7,256	6,772	6,760	6,067	5,326	5,707	1	5
Other vinyl resins[i]	190	212	220	222	212	195	190	187	186	177	208	–10	–1
Thermoplastic polyester	2,109	1,879	1,630	1,652	1,394	1,175	965	899	778	648	609	12	13
TOTAL	**48,529**	**47,047**	**43,543**	**44,614**	**41,485**	**37,746**	**35,202**	**33,744**	**31,067**	**26,949**	**28,652**	**3%**	**5%**

Note: Totals are for those products listed and exclude some small-volume plastics. **a** Dry-weight basis unless otherwise specified. **b** Unmodified. **c** Includes other tar acid resins. **d** Gross-weight basis. **e** Unsaturated; estimate. **f** Density 0.940 and below. **g** Density above 0.940. **h** Includes styrene-butadiene copolymers and other styrene-based polymers. **i** Includes polyvinyl butyral, polyvinyl formal, and polyvinylidene-chloride. **Source:** Society of the Plastics Industry


Plastics


Synthetic noncellulosic fibers

SYNTHETIC FIBERS: Gains in polyester, polyolefins help fibers recover

	Production											% annual change	
Millions of lb	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1990–91	1981–91
NONCELLULOSIC FIBERS													
Acrylic[a]	454	506	543	588	592	616	631	671	671	624	691	–11%	–4%
Nylon[b]	2537	2662	2740	2669	2689	2514	2343	2412	2419	1927	2332	–5	1
Olefin[c]	1865	1822	1639	1588	1494	1393	1249	997	906	723	785	2	9
Polyester	3410	3195	3594	3681	3541	3305	3341	3392	3544	3196	4176	7	–2
CELLULOSIC FIBERS													
Acetate[d]	486	505	580	614	605	619	558	199	229	196	261	–4	–5
Rayon								421	401	388	509		
TOTAL	**8752**	**8690**	**9096**	**9140**	**8921**	**8447**	**8122**	**8092**	**8168**	**7027**	**8754**	**1%**	**0%**

a Includes modacrylic. **b** Excludes aramid since 1982. **c** Includes olefin yarn and monofilaments and olefin and vinyon staple, tow, and fiberfill. **d** Includes diacetate and triacetate; excludes production for cigarette filters. **Source:** Fiber Economics Bureau

SYNTHETIC RUBBER: Output in 1991 was down for third consecutive year

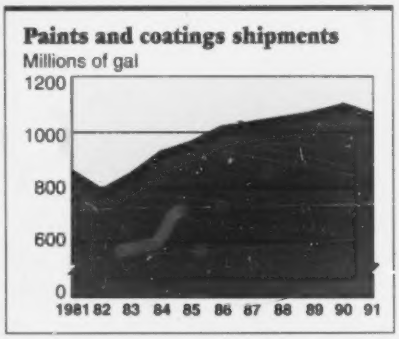
	Production											% annual change	
Thousands of metric tons	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1990–91	1981–91
Ethylene-propylene	232	266	260	263	254	230	215	215	175	123	178	−13%	3%
Nitrile	57	56	70	76	69	59	53	67	55	45	66	0	−1
Polybutadiene	415	412	452	407	371	336	330	359	333	288	342	−1	2
Styrene-butadiene rubber	843	853	884	909	850	792	735	958	904	876	1032	−1	−2
Other[a]	668	725	662	679	638	596	505	556	468	498	404	−8	5
TOTAL	**2215**	**2312**	**2328**	**2334**	**2182**	**2013**	**1838**	**2155**	**1935**	**1830**	**2022**	**−4%**	**1%**

a Includes butyl, polychloroprene, polyisoprene, silicone, and other synthetic elastomers. Some values are estimated. **Sources:** International Institute of Synthetic Rubber Producers; Rubber Manufacturers Association

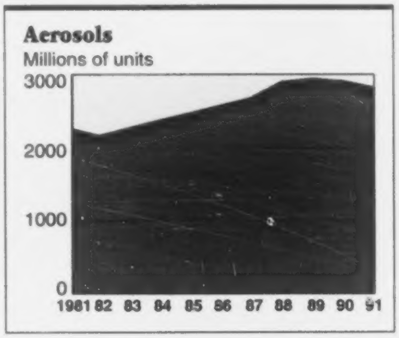
PAINTS AND COATINGS: Shipments slip after nearly a decade of rising steadily

	Shipments											% annual change	
Millions of gal	1991[a]	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1990–91	1981–91
Architectural	521	557	537	536	527	498	478	457	433	374	417	–6%	2%
Product[b]	361	346	360	364	340	368	352	336	294	280	312	4	2
Special purpose	168	197	179	154	146	135	145	145	130	129	129	–15	1
TOTAL	**1050**	**1100**	**1076**	**1054**	**1013**	**1001**	**975**	**938**	**857**	**783**	**858**	**–5%**	**1%**

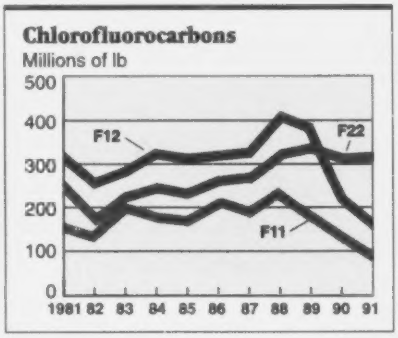
a Preliminary. b For original equipment manufacturers. **Source:** Department of Commerce


Paints and coatings shipments

Millions of gal


Aerosols

Millions of units


Chlorofluorocarbons

Millions of lb

AEROSOLS: Decline in personal product uses drops production for second year

	Production[a]											% annual change	
Millions of units	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1990–91	1981–91
Personal products	905	1050	1015	1100	964	952	879	832	747	628	645	–3%	3%
Household products	690	680	680	650	640	635	630	603	586	556	575	1	2
Automotive and industrial products	450	415	475	440	379	375	342	337	303	286	302	8	4
Paints and finishes	350	350	350	331	307	297	290	307	300	295	313	0	1
Insect sprays	200	190	197	190	190	193	190	184	180	166	173	5	2
Food products	192	175	175	157	140	136	140	138	132	131	145	10	3
Animal products	8	8	8	8	22	22	15	16	19	19	14	0	–5
Miscellaneous	19	15	12	31	80	18	23	15	15	13	28	27	4
TOTAL	**2814**	**2883**	**2912**	**2907**	**2722**	**2628**	**2509**	**2432**	**2282**	**2094**	**2195**	**–2%**	**3%**

a Includes Puerto Rico. **Source:** Chemical Specialties Manufacturers Association

CHLOROFLUOROCARBONS: Production of nonhydrogenated CFCs fell 27% last year

	Production											% annual change	
Millions of lb	1991[a]	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1990–91	1981–91
Chlorodifluoromethane (CFC-22)	309[b]	306	343	333	275	271	235	254	236	174	252	1%	2%
Dichlorodifluoromethane (CFC-12)	153	209	392	414	335	322	302	337	290	258	325	–27	–3
Trichlorofluoromethane (CFC-11)	99	135	192	249	198	202	176	185	215	140	163	–27	–3
All other fluorinated hydrocarbons[c]	na	na	385	379	354	344	306	337	279	na	na	—	—
TOTAL	**na**	**na**	**1312**	**1374**	**1162**	**1139**	**1019**	**1113**	**1020**	**na**	**na**	**—**	**—**

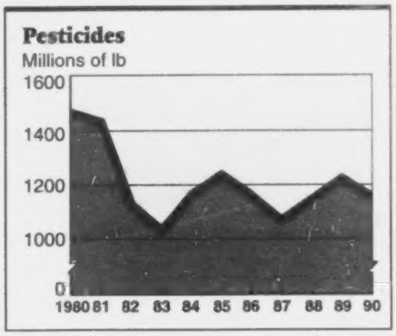
a Preliminary. b C&EN estimate. c Includes other fluorohalogenated hydrocarbons. **na** = not available. **Source:** International Trade Commission

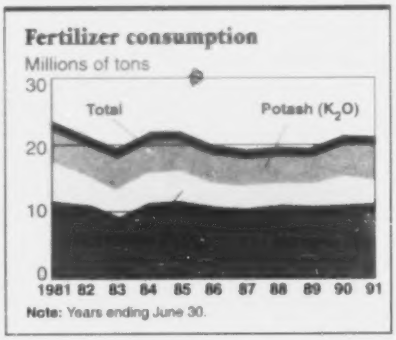
1 PRODUCTION BY THE U.S. CHEMICAL INDUSTRY

PESTICIDES: Stalled growth ends decade that never recovered from early 1980s tumble

	Production											% annual change	
Millions of lb	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1989–90	1980–90
Herbicides[a]	698	697	702	556	725	756	716	604	623	839	806	0%	–1%
Insecticides[b]	386	424	352	379	342	370	350	306	379	448	506	–9	–7
Fungicides[c]	96	111	110	105	113	109	123	106	111	143	156	–14	–5
TOTAL	**1180**	**1232**	**1164**	**1040**	**1180**	**1235**	**1189**	**1017**	**1113**	**1430**	**1468**	**–4%**	**–2%**

a Includes plant growth regulators. **b** Includes rodenticides, soil conditioners, and fumigants. **c** Includes dithiocarbamates. **Source:** International Trade Commission





Note: Years ending June 30.

FERTILIZER CONSUMPTION: Nitrogen is only major nutrient whose use was up last year

	Consumption											% annual change	
Thousands of tons	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1990–91	1981–91
Nitrogen (N)	11,179	11,076	10,593	10,512	10,210	10,424	11,493	11,092	9,127	10,983	11,924	1%	–1%
Phosphates (P_2O_5)	4,151	4,345	4,117	4,129	4,008	4,178	4,658	4,901	4,138	4,814	5,434	–4	–3
Potash (K_2O)	4,984	5,203	4,838	4,973	4,837	5,053	5,553	5,797	4,831	5,631	6,320	–4	–2
TOTAL	**20,314**	**20,624**	**19,548**	**19,614**	**19,055**	**19,655**	**21,704**	**21,790**	**18,096**	**21,428**	**23,678**	**–2%**	**–2%**

Note: Years ending June 30. **Source:** Fertilizer Institute

FERTILIZER PRODUCTION: Ammonia was flat, most other fertilizers declined in 1991

										% annual change	
Thousands of tons	1991	1990	1989	1988	1987	1986	1985	1984	1983	1990–91	1983–91
NITROGEN PRODUCTS											
Ammonia	14,191	14,167	14,192	14,136	13,357	12,565	16,594	16,613	13,361	0%	1%
Ammonium nitrate	2,551	2,579	2,528	2,765	2,472	2,250	3,178	3,365	3,232	–1	–2
Ammonium sulfate	2,199	2,395	2,327	2,260	2,153	2,058	2,343	2,078	1,969	–8	2
Urea	4,258	4,231	4,253	4,501	4,253	3,564	3,975	4,889	4,112	1	0
Nitrogen solutions	na	4,750	5,644	6,999	5,988	5,945	7,928	7,999	6,385	na	na
PHOSPHATE PRODUCTS											
Diammonium phosphate	13,569	13,860	13,507	11,575	9,537	7,492	10,800	12,358	10,264	–2	3
Monoammonium phosphate	2,219	2,252	1,991	1,818	1,679	1,416	1,641	1,654	1,423	–2	5
Concentrated superphosphate	1,914	1,998	1,777	2,032	2,049	2,127	2,570	2,404	2,684	–4	–3
Phosphate rock	44,877	44,311	47,676	42,220	39,330	36,227	49,348	47,465	40,664	1	0
Phosphoric acid (P_2O_5)	10,913	11,344	10,962	10,234	8,903	8,085	9,837	10,899	9,182	–4	2
POTASH PRODUCTS											
Potassium chloride	2,387	2,350	2,316	2,243	1,810	1,715	1,713	2,168	1,928	2	2

Note: Figures are based on Fertilizer Institute surveys and may not represent the entire industry. **na**=not available. **Source:** Fertilizer Institute

2

FINANCES OF THE U.S. CHEMICAL INDUSTRY

Poor showing for chemical makers

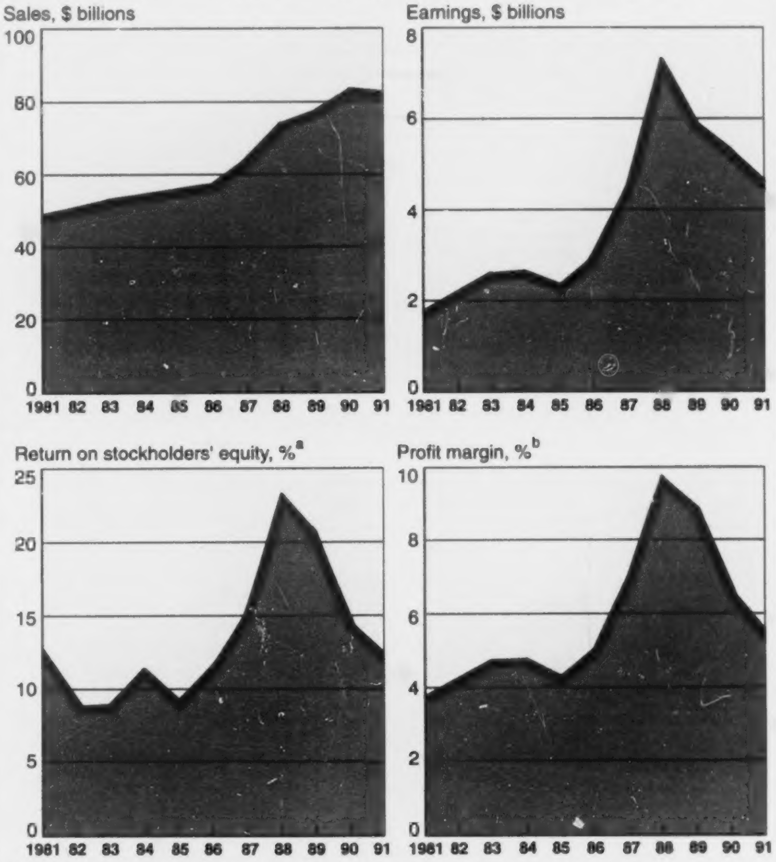
Poor financial results characterized chemical performance in 1991. Sales, earnings, and profitability all fell from 1990 levels. These results came as little surprise to industry analysts who had forecast a slow first half for 1991 with something of a rebound coming sometime in the second six months. To a certain degree, that forecast came true. However, whereas some companies saw an upturn, especially in the fourth quarter, the improvement was not widespread enough nor strong enough to counter the drop that had occurred earlier in the year.

Although growth in demand could only be described as lackluster in 1991, the real culprit in declining financial results was pricing. The value of shipments of chemicals and allied products in 1991 increased less than 1% over the previous year, but for industrial chemicals, which account for most of the fortunes of the traditional chemical industry, the value of shipments fell almost 3%. The government's producer price index for chemicals and allied products rose about 1.6% through 1991, but the index for industrial chemicals dropped about 7%.

The result of the declining demand and prices was, naturally, falling fortunes within the industry. For the 30 companies C&EN regularly surveys, which produce mostly industrial chemicals, sales fell about 1% to $82.4 billion. At the same time, earnings dropped 16% to $4.47 billion, their lowest level since 1987 and their third straight year of decline. Profitability for the group declined to its lowest level since 1986: Earnings as a percentage of sales fell to 5.3% in 1991 from 6.4% the year before, and earnings as a percentage of stockholders' equity declined to 12.1% last year from 14.1% the year before.

In 1991 all measures of profitability showed enormous declines from the recent highs set in 1988. Profit margins (earnings as a percentage of sales) dropped from 9.5% to 5.3% while earnings as a percent of stockholders' equity fell by almost a half from 23% to 12%.

Everything—sales, earnings, profitability—fell in 1991



Note: Based on data for 30 major chemical companies. a After-tax earnings as a percentage of year-end stockholders' equity. b After-tax earnings as a percentage of sales.

Last year's results were helped by a good balance of trade. The value of exports rose about 10% and the value of imports increased less than 8%, leading to a 14% increase in the chemical trade surplus for 1991. Here again, though, prices had a moderating effect. In some cases—notably plastics—sales volume grew significantly over the year before, but the prices of materials sold abroad often did not match U.S. prices. Thus, the value of exports didn't increase as much as did their physical volume.

If there is anything hopeful to be seen in 1991, it may be that by the end of the year, although the 30 chemical companies as a group were still suffering from declining earnings, most of this decline was accounted for by only a few commodity-producing companies. For instance, in the fourth quarter, only seven of the 30 companies reported earnings declines from fourth-quarter 1990. This trend has continued into 1992, when in the first quarter, 24 of the companies reported earnings improvement over the like period of 1991.

TOP 100 CHEMICAL PRODUCERS: Nearly half saw chemical sales drop last year

Rank 1991	Rank 1990		Chemical sales 1991 ($ millions)	Change from 1990	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1990	Chemical operating profits as % of total profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
1	1	**Du Pont**	$15,383	−1.2%	39.8%	Diversified	$1265	−35.7%	36.2%	8.2%	$13,505	42.4%	9.4%
2	2	**Dow Chemical**	13,277	−9.6	70.6	Basic chemicals	835	−56.6	40.7	6.3	13,460	54.4	6.2
3	3	**Exxon**	10,703	−4.0	9.3	Petroleum	672	−8.8	7.6	6.3	8,630	9.9	7.8
4	6	**Hoechst Celanese**	6,347	15.4	93.4	Basic chemicals	488	14.3	103.2	7.7	na	na	na
5	5	**Monsanto**	5,451	−4.6	61.5	Basic chemicals	694	11.2	68.6	12.7	4,754	51.5	14.6
6	4	**Union Carbide**	4,877	−6.9	100.0	Basic chemicals	122	−80.4	100.0	2.5	4,761	100.0	2.6
7	7	**General Electric**	4,722[d]	−8.6	7.8	Diversified	803	−21.0	10.1	17.0	8,340	5.0	9.6
8	8	**Occidental Petroleum**	4,649	−7.8	40.4	Petroleum	53	−91.7	5.0	1.1	5,150	32.0	1.0
9	9	**BASF**	3,959	−9.3	79.8	Basic chemicals	na	na	na	na	na	na	na
10	11	**Mobil**	3,953	−3.2	6.3	Petroleum	245	−38.3	5.2	6.2	3,294	7.8	7.4
11	10	**Amoco**	3,893	−4.7	13.8	Petroleum	56	−77.8	2.3	1.4	3,858	12.8	1.5
12	13	**Eastman Kodak**	3,740	4.2	19.3	Photo equipment	538	−10.6	22.6	14.4	4,035	16.7	13.3
13	14	**W. R. Grace**	3,531	−1.1	58.4	Specialty chemicals	426	−1.2	118.7	12.1	2,677	44.6	15.9
14	12	**Shell Oil**	3,378	−9.1	15.2	Petroleum	264	−49.1	57.0	7.8	3,989	14.2	6.6
15	15	**Chevron**	3,098	−6.8	7.7	Petroleum	196	345.5	7.3	6.3	2,612	8.0	7.5
16	16	**Arco Chemical**	2,837	0.2	100.0	Basic chemicals	398	−15.1	100.0	14.0	3,676	100.0	10.8
17	17	**Rohm & Haas**	2,763	−2.2	100.0	Basic chemicals	327	−6.8	100.0	11.8	2,495	100.0	13.1
18	19	**Air Products[e]**	2,676	2.4	91.3	Basic chemicals	474	7.7	108.4	17.7	3,445	90.7	13.8
19	20	**Miles**	2,479	11.4	40.0	Diversified chemicals	na	na	na	na	na	na	na
20	—	**Union Carbide Ind. Gases**	2,469	2.0	92.5	Basic chemicals	324	−20.8	100.0	13.1	3,451	100.0	9.4
21	18	**Allied-Signal**	2,459	−11.7	20.8	Diversified	183	−36.2	32.9	7.4	1,949	18.8	9.4
22	22	**American Cyanamid**	2,344	4.0	47.0	Basic chemicals	222	13.8	36.7	9.5	1,788	48.2	12.4
23	21	**Rhône-Poulenc**	2,300	1.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
24	23	**Ashland Oil[e]**	2,285	1.8	23.2	Petroleum	98	40.0	33.3	4.3	834	15.3	11.8
25	24	**Hercules**	2,172	−1.0	74.2	Basic chemicals	201	20.4	101.5	9.3	1,913	72.5	10.5
26	26	**Ciba-Geigy**	2,151	10.0	52.0	Specialty chemicals	na	na	na	na	na	na	na
27	29	**Akzo**	1,913	1.0	100.0	Basic chemicals	na	na	na	na	na	na	na
28	25	**Phillips Petroleum**	1,904	−10.2	15.1	Petroleum	297	−33.7	24.0	15.6	1,970	17.2	15.1
29	27	**Quantum Chemical**	1,885	−3.8	74.4	Basic chemicals	99	−59.3	112.7	5.2	2,219	69.4	4.4
30	33	**Dow Corning**	1,845	7.4	100.0	Specialty chemicals	na	na	na	na	na	na	na
31	31	**Aluminum Co. of America**	1,842	0	18.6	Nonferrous metals	535	−59.5	114.7	29.0	2,690	24.8	19.9
32	28	**B. F. Goodrich**	1,778	−8.3	71.9	Basic chemicals	35	−73.2	49.8	1.9	1,425	67.4	2.4
33	34	**National Starch**	1,756	5.1	100.0	Specialty chemicals	269	5.9	100.0	15.3	1,635	100.0	16.5
34	35	**FMC**	1,684	3.7	43.2	Machinery	203	6.0	46.4	12.1	1,455	58.9	14.0
35	30	**Lyondell Petrochemical**	1,666	−11.8	32.0	Petroleum products	249	−44.4	47.7	14.9	na	na	na
36	36	**Ethyl**	1,535	−3.5	59.6	Basic chemicals	231	−25.1	59.2	15.0	1,320	16.7	17.5
37	32	**Texaco**	1,515	−12.1	4.1	Petroleum	4	−93.3	0.3	0.3	1,398	6.7	0.3
38	37	**Elf Atochem**	1,500	−2.6	100.0	Basic chemicals	na	na	na	na	na	na	na
39	38	**Degussa**	1,359	−5.2	85.0	Specialty chemicals	na	na	na	na	na	na	na
40	39	**Lubrizol**	1,349	1.0	91.4	Specialty chemicals	179	−55.0	106.9	13.3	862	73.6	20.8
41	48	**Great Lakes Chemical**	1,308	22.6	100.0	Specialty chemicals	350	20.8	100.0	26.8	1,649	100.0	21.2
42	44	**Nalco Chemical**	1,237	2.1	100.0	Specialty chemicals	227	7.6	100.0	18.3	1,324	100.0	17.1
43	50	**Morton International[f]**	1,215	18.9	63.7	Specialty chemicals	153	9.7	71.4	12.6	1,225	68.8	12.5
44	43	**Unocal**	1,213	−1.9	11.1	Petroleum	89	−22.6	42.0	7.3	662	6.7	13.4
45	40	**Huntsman Chemical**	1,200	−7.7	100.0	Basic chemicals	na	na	na	na	na	na	na
46	41	**Tenneco**	1,160	−10.6	8.5	Diversified	66	−60.5	12.0	5.7	1,443	7.9	4.6
47	47	**IMC Fertilizer[f]**	1,131	2.3	100.0	Agrochemicals	196	14.6	100.0	17.3	1,739	100.0	11.3
48	46	**Cabot[e]**	1,129	2.0	76.1	Basic chemicals	103	−29.9	91.6	9.1	1,060	72.5	9.7
49	49	**Imcera Group[f]**	1,127	10.0	69.0	Specialty chemicals	135	29.1	72.9	11.9	1,124	49.9	12.0
50	45	**PPG Industries**	1,100	−4.3	19.4	Glass products	195	−15.6	34.3	17.7	1,076	17.8	18.1

CIRCLE 6 ON READER SERVICE CARD →

Rank 1991	Rank 1990		Chemical sales 1991 ($ millions)	Change from 1990	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1990	Chemical operating profits as % of total profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
51	54	**Farmland Industries[g]**	$1036	7.3%	28.5%	Agricultural supplies	$123	47.3%	85.3%	11.9%	$442	38.3%	27.9%
52	56	**Inspiration Resources**	1023	6.4	96.4	Agrochemicals	35	46.2	82.4	3.4	352	70.4	10.0
53	55	**International Flavors**	1017	5.6	100.0	Specialty chemicals	254	4.5	100.0	25.0	1217	100.0	20.9
54	52	**Solvay America**	1010	1.3	100.0	Basic chemicals	na	na	na	na	na	na	na
55	51	**Reichhold Chemicals**	1000	0.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
56	42	**Olin**	960	−24.3	42.2	Basic chemicals	na	na	na	na	982	48.8	na
57	60	**Freeport-McMoRan**	880	6.7	55.8	Agrochemicals	71	37.4	31.7	8.1	1143	32.1	6.2
58	64	**H. B. Fuller[h]**	853	7.7	100.0	Specialty chemicals	60	15.3	100.0	7.0	509	100.0	11.8
59	53	**Aristech**	844	−13.3	100.0	Basic chemicals	na	na	na	na	na	na	na
60	58	**NL Industries**	840	−7.3	100.0	Basic chemicals	139	−44.7	100.0	16.5	1831	100.0	7.6
61	57	**Georgia Gulf**	838	−10.1	100.0	Basic chemicals	171	−25.4	100.0	20.3	416	100.0	41.0
62	62	**Uniroyal Chemical**	832	3.0	100.0	Specialty chemicals	102	−5.6	100.0	12.3	1143	100.0	9.0
63	63	**Engelhard**	809	0.3	33.2	Diversified	111	10.8	69.8	13.7	813	64.7	13.6
64	59	**CF Industries**	803	−11.1	100.0	Agrochemicals	78	71.2	100.0	9.7	837	100.0	9.3
65	65	**Witco[i]**	793	3.1	48.6	Specialty chemicals	72	−12.6	52.5	9.0	478	39.9	15.0
66	71	**Pfizer**	730	−18.1	10.5	Drugs	57	−17.4	5.7	7.8	795	8.3	7.2
67	66	**Vista Chemicals[e]**	705	−1.9	100.0	Basic chemicals	na	na	na	na	na	na	na
68	—	**CBI Industries**	698	5.4	43.2	Construction	107	4.3	63.8	15.3	na	na	na
69	61	**Fina**	667	−18.0	20.5	Petroleum	103	−35.4	87.9	15.5	462	16.1	22.4
70	68	**Betz Laboratories**	666	11.5	100.0	Specialty chemicals	119	14.3	100.0	17.9	476	100.0	25.06.8
71	70	**Merck**	583	5.8	6.8	Drugs	78	15.5	2.6	13.4	548	8.6	14.3
72	69	**Loctite**	561	1.1	100.0	Specialty chemicals	99	0.5	100.0	17.6	529	100.0	18.7
73	73	**Sterling Chemical[e]**	543	27.0	100.0	Basic chemicals	61	−30.1	100.0	9.4	361	100.0	16.8
74	77	**Intl. Specialty Products**	526	2.8	100.0	Specialty chemicals	141	5.6	100.0	26.7	na	na	na
75	78	**Hüls**	500	7.5	100.0	Specialty chemicals	na	na	na	na	na	na	na
76	80	**Sigma-Aldrich**	498	13.2	84.5	Specialty chemicals	119	14.9	96.0	23.9	529	88.7	22.5
77	72	**Ferro**	476	−7.2	45.0	Specialty materials	9	−8.0	12.2	1.9	248	44.9	3.7
78	79	**Union Camp**	471	2.3	15.9	Diversified	27	20.3	9.7	5.7	358	7.6	7.5
79	67	**Kerr-McGee**	454	−29.3	13.9	Petroleum	101	−17.9	37.8	22.2	755	24.2	13.4
80	—	**Rexene**	450	−10.4	100.0	Basic chemicals	12	−85.2	100.0	2.7	441	100.0	2.7
81	81	**Dexter**	429	−2.2	45.7	Specialty chemicals	3	−91.4	8.0	0.8	299	44.2	1.1
82	82	**Borden Chemicals**	420	−0.1	100.0	Basic chemicals	93	8.4	100.0	22.0	507	100.0	18.2
83	76	**Sun Co.**	415	−14.6	3.5	Petroleum	na	na	na	na	na	na	na
84	84	**Stepan**	414	16.3	100.0	Specialty chemicals	21	−9.1	100.0	5.2	233	100.0	9.2
85	83	**Vulcan Materials**	359	−12.2	35.7	Nonmetallic minerals	43	−41.2	50.5	11.9	na	na	na
86	85	**Crompton & Knowles**	341	9.6	75.7	Specialty chemicals	51	19.0	72.0	15.1	252	84.2	20.4
87	—	**Lonza**	330	10.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
88	86	**First Mississippi[f]**	327	10.8	60.9	Agrochemicals	36	58.2	128.1	11.1	173	38.3	21.1
89	90	**Mississippi Chemical[f]**	322	27.4	100.0	Farm cooperative	39	691.9	100.0	12.0	325	100.0	11.9
90	87	**Calgon Carbon**	308	8.2	100.0	Basic chemicals	61	−1.9	100.0	19.9	336	100.0	18.2
91	88	**Petrolite[j]**	305	7.7	94.1	Specialty chemicals	22	32.8	91.1	7.3	196	80.3	11.4
92	75	**Nova**	263	−46.3	100.0	Basic chemicals	na	na	na	na	na	na	na
93	91	**Georgia-Pacific**	223	−9.7	3.7	Wood products	na	na	na	na	na	na	na
94	93	**Sequa Corp.**	213	6.0	11.3	Diversified	37	23.8	31.2	17.2	127	6.0	28.9
95	92	**Quaker Chemical**	191	−5.2	100.0	Specialty chemicals	15	28.6	100.0	8.1	156	100.0	9.9
96	94	**Sherex**	168	−5.4	100.0	Specialty chemicals	na	na	na	na	na	na	na
97	95	**Lawter International**	153	1.9	100.0	Specialty chemicals	30	8.9	100.0	19.7	178	100.0	16.9
98	97	**Cambrex Corp.**	144	8.1	100.0	Specialty chemicals	0[k]	−93.1	100.0	0.2	112	100.0	0.3
99	96	**LeaRonal[l]**	142	1.3	100.0	Specialty chemicals	10	−27.0	100.0	7.2	92	100.0	11.1
100	100	**Sybron**	131	2.7	100.0	Specialty chemicals	na	na	na	na	na	na	na

a Operating profit is sales less administrative expenses and cost of sales. **b** Chemical operating profit as a percentage of sales. **c** Chemical operating profit as a percentage of identifiable chemical assets. **d** Chemical sales include significant amounts of nonchemical products. **e** Fiscal year ended Sept. 30. **f** Fiscal year ended June 30. **g** Fiscal year ended Aug. 31. **h** Fiscal year ended Nov. 30. **i** Does not include all chemical sales. **j** Fiscal year ended Oct. 31. **k** Because of rounding $300,000 does not show. **l** Fiscal year ended Feb. 28, 1991. **na** = not available.

— CIRCLE 6 ON READER SERVICE CARD

FINANCIAL ANALYSIS: Most measures of chemical company performance declined in 1991

		Profit margin[a]	Return on investment[b]	Debt as % of debt plus equity	% total sales abroad[c]	% total assets abroad[d]	Sales per employee[e]	Dividends as % of net income	CAPITAL SPENDING[f]		R&D as % of sales	Sales as % of assets	Net plant as % of gross plant
									as % of sales	as % of net plant			
SALES OVER $1.5 BILLION													
Air Products[g]	1991	8.5%	4.0%	33.9%	26.7%	31.8%	$201	33.7%	17.3%	19.3%	2.7%	69.3%	49.2%
	1990	7.9	3.9	36.1	24.5	35.5	207	33.4	16.2	18.8	2.5	74.2	49.6
American Cyanamid	1991	7.2	5.8	12.8	38.7	27.0	158	38.0	7.9	19.4	9.9	98.7	52.1
	1990	2.4	1.7	13.1	39.6	27.2	143	118.9	8.2	19.7	10.1	89.8	51.5
Arco Chemical	1991	5.6	3.7	39.8	43.8	36.9	645	158.9	16.0	20.1	2.4	74.0	73.0
	1990	9.4	6.8	40.2	44.4	36.6	702	91.6	19.4	30.5	2.1	74.3	71.7
Dow Chemical	1991	5.1	3.4	39.2	51.7	44.0	302	73.6	10.2	21.9	6.2	76.1	42.5
	1990	7.0	5.1	37.4	52.0	45.4	318	51.4	10.7	25.7	5.7	82.5	43.1
Ethyl	1991	8.3	10.3	39.9	19.3	5.5	429	33.2	6.5	21.7	2.7	32.6	51.2
	1990	8.9	12.0	39.5	21.2	4.9	441	112.1	6.0	22.4	2.6	37.6	50.8
Freeport-McMoRan	1991	6.1	2.3	83.3	29.6	na	na	179.9	50.9	35.7	na	44.3	67.0
	1990	1.7	0.7	82.4	27.3	na	na	564.0	39.0	27.9	na	57.0	63.5
B. F. Goodrich	1991	0.2	0.2	22.1	20.9	18.6	171	1337.5	8.5	18.0	3.1	108.9	56.8
	1990	2.5	2.3	13.2	24.7	18.6	165	100.6	10.0	21.9	3.0	102.8	60.3
W. R. Grace	1991	3.6	3.1	47.0	41.1	31.8	130	55.9	7.4	17.5	2.5	100.7	51.1
	1990	3.0	2.8	50.7	36.9	34.1	138	59.5	7.6	20.9	2.2	108.5	50.2
Hercules	1991	4.7	3.0	20.1	30.0	21.5	169	76.4	7.3	14.5	2.9	84.5	45.5
	1990	3.0	2.4	23.6	27.8	18.6	161	109.4	8.5	18.8	2.9	86.5	47.3
Imcera Group[h]	1991	5.9	4.7	23.2	34.3	25.3	164	24.4	7.6	19.6	4.9	72.6	66.7
	1990	4.1	3.7	47.8	34.4	27.3	148	43.8	6.0	14.6	5.3	66.9	69.2
Monsanto	1991	7.0	5.5	33.9	36.4	34.2	226	41.5	6.7	17.6	8.0	96.1	42.5
	1990	6.1	4.9	28.8	36.8	32.4	219	44.3	8.3	21.5	7.7	97.4	45.8
Morton International[h]	1991	7.3	7.0	18.8	29.4	23.9	187	32.7	8.6	22.6	3.1	99.0	58.8
	1990	8.2	7.4	20.6	30.4	25.6	169	30.7	6.8	17.2	2.9	90.4	59.7
Olin	1991	3.0	2.1	43.8	7.6	10.0	158	72.4	7.8	19.7	1.8	113.1	37.0
	1990	3.2	2.8	39.5	7.8	10.9	171	58.3	7.2	22.6	2.5	138.9	36.1
PPG Industries	1991	4.5	3.0	29.8	36.1	34.0	168	71.6	5.8	10.4	3.9	93.7	51.2
	1990	7.9	5.8	31.1	34.3	33.5	172	37.0	6.9	12.8	3.6	98.6	54.3
Quantum	1991	def	def	108.8	na	na	na	0	6.3	8.1	1.9	79.2	67.3
	1990	0.8	0.6	104.2	na	na	na	0	17.3	22.7	1.8	82.4	69.5
Rohm & Haas	1991	5.9	3.9	36.8	50.1	32.8	215	49.1	9.6	18.0	6.6	95.4	48.8
	1990	7.3	5.5	32.7	43.7	32.4	219	38.2	14.6	29.6	6.3	104.5	50.2
Union Carbide	1991[i]	0.9	0.5	34.1	27.6	17.1	292	352.3	8.2	16.0	3.2	71.4	45.1
	1990	4.6	3.0	49.6	36.2	32.3	204	39.1	9.8	17.2	2.5	87.3	48.5
Witco	1991	4.5	4.7	22.3	21.1	20.9	236	52.6	4.6	15.7	1.7	136.1	47.9
	1990	4.2	4.4	28.2	19.8	20.2	225	56.4	5.6	19.3	1.6	138.4	48.8
AVERAGE 1991		4.9%	3.4%	38.9%	37.2%	30.4%	$214	67.3%	9.6%	18.9%	4.9%	80.0%	49.3%
AVERAGE 1990		5.5	4.1	39.7	37.2	32.2	210	57.9	10.4	21.8	4.5	85.5	50.2

		Profit margin[a]	Return on investment[b]	Debt as % of debt plus equity	% total sales abroad[c]	% total assets abroad[d]	Sales per employee[e]	Dividends as % of net income	CAPITAL SPENDING[f]		R&D as % of sales	Sales as % of assets	Net plant as % of gross plant
									as % of sales	as % of net plant			
SALES LESS THAN $1.5 BILLION													
Betz Laboratories	1991	11.3%	11.6%	27.6%	19.8%	22.5%	$167	54.4%	8.8%	22.9%	4.0%	139.9%	56.4%
	1990	11.0	11.3	31.0	19.0	22.0	162	56.2	9.6	24.6	3.9	139.7	57.9
Cabot[g]	1991	2.7	2.4	46.4	45.8	42.6	280	66.0	13.4	29.5	2.5	101.3	59.0
	1990	4.2	3.4	45.7	41.8	36.0	279	41.8	10.4	19.9	2.1	96.6	57.3
Calgon Carbon	1991	18.3	10.0	10.7	56.2	35.2	138	17.1	33.9	35.0	2.8	62.0	77.9
	1990	13.9	12.4	5.3	39.2	43.5	190	15.4	16.7	33.0	2.0	99.9	76.4
Crompton & Knowles	1991	8.0	13.1	35.1	15.8	18.8	252	32.8	2.5	14.3	2.1	145.9	90.1
	1990	7.7	10.4	37.4	18.7	19.2	192	31.2	4.2	21.3	2.2	138.0	62.1
First Mississippi[h]	1991	1.0	0.9	38.8	27.3	na	na	110.0	8.8	16.0	na	112.6	63.7
	1990	0.9	0.5	39.7	24.0	na	na	135.0	13.0	20.8	na	97.2	45.0
H. B. Fuller[j]	1991	3.2	4.5	24.7	47.7	54.2	152	20.2	3.5	14.4	2.0	168.9	59.0
	1990	2.7	3.7	30.9	46.3	54.2	142	25.7	4.0	15.6	2.0	161.9	61.3
Georgia Gulf	1991	7.3	11.9	255.1	na	na	760	0	3.4	12.8	na	201.7	64.8
	1990	10.2	17.9	263.9	na	na	868	0	6.2	27.1	na	204.1	68.0
Great Lakes Chemical	1991	12.0	11.8	13.4	45.5	37.7	na	12.1	5.4	17.6	3.0	79.3	58.5
	1990	13.2	11.5	9.2	53.1	42.7	na	11.5	4.6	13.3	2.7	75.8	59.5
International Flavors	1991	16.3	11.4	0	68.9	45.6	241	54.4	5.2	18.4	6.1	83.5	51.4
	1990	16.3	11.4	0	70.1	46.6	230	52.5	4.3	15.5	6.0	85.3	51.7
Lawter International	1991	17.3	13.3	4.3	43.3	30.0	307	56.5	5.8	26.0	2.5	85.8	46.3
	1990	15.6	13.4	4.7	43.7	32.1	321	53.7	4.1	21.7	2.5	97.7	43.2
Loctite	1991	13.6	14.7	6.6	60.1	66.4	156	31.5	6.0	27.8	4.0	106.1	56.0
	1990	12.1	13.0	9.8	55.0	65.5	151	31.2	5.1	27.4	3.9	113.5	55.6
Lubrizol	1991	8.4	7.4	4.2	53.7	[illegible]	277	43.1	5.6	21.7	5.4	125.3	39.5
	1990	13.2	12.2	6.8	56.8	43.7	280	27.5	5.4	21.9	5.2	129.6	39.9
Nalco Chemical	1991	10.9	9.1	42.7	38.6	34.2	181	50.4	11.1	27.7	3.8	93.4	51.5
	1990	10.8	10.5	38.3	28.2	20.4	207	48.2	9.5	27.4	3.7	116.9	49.9
Petrolite[k]	1991	4.6	3.9	0	32.4	28.5	na	86.1	6.5	19.5	3.5	132.6	41.2
	1990	4.4	3.4	2.3	31.3	37.5	na	96.7	5.8	14.8	4.1	118.9	44.5
Quaker	1991	5.6	6.3	5.0	39.8	35.1	186	44.2	4.4	17.3	na	112.8	54.7
	1990	7.0	8.4	5.2	41.1	35.0	187	30.5	6.3	27.3	na	132.2	55.3
Sigma-Aldrich	1991	13.5	11.4	13.6	28.5	29.3	140	14.2	4.4	13.6	na	98.8	61.5
	1990	13.5	11.3	16.1	28.1	29.0	129	14.3	6.1	16.9	na	96.9	66.2
Stepan	1991	3.0	2.9	49.7	14.2	14.2	314	28.7	8.1	21.5	3.7	152.5	48.7
	1990	3.7	3.8	48.3	11.7	13.6	297	22.0	9.8	26.8	3.4	157.7	49.6
Sterling Chemical[g]	1991	6.8	8.6	38.8	45.2	na	571	97.2	6.3	14.9	na	150.3	74.9
	1990	11.7	14.8	37.1	35.4	na	na	93.6	3.9	9.2	na	143.8	78.8
AVERAGE 1991		**8.8%**	**8.4%**	**27.8%**	**43.1%**	**37.5%**	**$226**	**38.8%**	**7.4%**	**21.7%**	**3.7%**	**109.9%**	**55.9%**
AVERAGE 1990		**9.7**	**9.1**	**30.2**	**41.6**	**36.6**	**216**	**35.3**	**7.1**	**20.6**	**3.5**	**112.8**	**54.6**

Note: Net income is from continuing operations, excluding extraordinary and nonrecurring items where possible. **a** Net income as a percentage of sales. **b** Net income as a percentage of current assets plus gross plant. **c** Consolidated sales only. **d** Foreign identifiable assets as a percentage of total assets. **e** Thousands of dollars. **f** Actual spending on construction of new facilities and purchase of land and new equipment in consolidated businesses. **g** Fiscal year ended Sept. 30. **h** Fiscal year ended June 30. **i** Excludes industrial gases business. **j** Fiscal year ended Nov. 30. **k** Fiscal year ended Oct. 31. **na** = not available. **def** = deficit.

Chemical capital spending nose-dives

Chemical capital spending plummeted in 1991. Big budget projects felt the impact of the recession as the 25 major chemical firms that C&EN tracks annually skimmed the fat off their spending programs, with an average drop of 16% to a combined total of $9.0 billion. The 1991 drop was the largest since 1983, when industry overcapacity and recession forced these same companies to cut capital outlays 25% to hit the decade low of $5.0 billion for the group.

The 1991 spending decline follows three years of big increases, when sales and profits were generally healthier for the group than they were in 1991. From 1987 to 1990, chemical capital spending for these companies grew at an average rate of 21%, well above the 4% compound annual growth the group has made on plant outlays since 1981. Though most chemical companies began to experience the effects of the recession in late 1989, they were committed to building projects that kept capital outlays growing at 11% in 1990 to reach a 10-year high of nearly $11 billion.

Capital spending as a percentage of sales for these 25 companies also fell in 1991, to 9.4%. In each of the previous two years, spending as a percentage of sales set new highs for the decade: 10.9% in 1990 and 10.2% in 1989. The reason this percentage rose so fast is that although sales leveled off, chemical companies were still committed to spending projects they had planned in rosier times.

C&EN's sample of chemical firms includes one new company this year and excludes one previously listed. No longer in the group is Chemed, which early last year sold its principal chemical operations, DuBois Chemicals, to Diversey Corp., a subsidiary of Canadian brewer Molson. The newcomer to the list is H. B. Fuller, the St. Paul, Minn., manufacturer of specialty chemicals, and the table and accompanying graphs are all revised to reflect the change.

The Department of Commerce's much wider survey of the chemical industry draws a different picture of capital spending trends. This survey registers a 4% increase in capital expenditures in 1991 to $21.5 billion, and projects close to a 9% increase in capital outlays for the industry in 1992.

The C&EN data are restricted to companies that Commerce might characterize as producers of industrial chemicals and synthetic materials. These producers make up less than half of the companies Commerce considers chemical. Also included in the Commerce Department survey are manufacturers of chemical products such as pharmaceuticals, soaps, toiletries, and paints. Capital spending by all manufacturing companies declined almost 5% in 1991 to $184 billion, according to Commerce.

A separate Commerce survey shows that capital outlays abroad declined in 1991 for chemical companies and for all manufacturers for the first time since 1983. For chemical firms, those outlays dropped more than 4% in 1991, following a jump of nearly 24% in 1990. The survey predicts modest recovery in 1992, with expenditures by chemical companies abroad expected to reach $6.6 billion, almost 2% above 1991.

INDUSTRY CAPITAL SPENDING: Chemicals, petroleum outperform manufacturing generally

$ Billions	1992[a]	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982
Chemicals	$ 23.30	$ 21.45	$ 20.63	$ 18.47	$ 19.25	$ 16.42	$ 16.81	$ 16.44	$ 15.32	$ 12.96	$ 12.66
Iron and steel	6.42	6.64	7.78	7.87	6.16	4.69	3.32	4.12	3.54	3.25	3.78
Nonferrous metals	2.32	2.81	2.88	2.64	2.77	2.16	1.93	1.88	2.13	1.74	1.90
Paper	10.76	11.63	16.53	15.58	11.23	9.01	8.77	8.59	7.21	5.92	5.60
Petroleum	31.73	35.98	34.79	30.08	19.93	17.12	17.92	26.71	25.53	23.14	26.39
Rubber	3.65	3.44	3.48	3.79	3.86	3.52	3.89	3.86	3.11	2.46	2.16
Stone, clay, glass	3.09	2.89	3.29	4.00	3.59	3.37	3.14	3.40	3.09	2.77	2.90
All manufacturing	182.81	183.61	192.61	183.80	165.70	145.90	142.69	153.48	138.82	116.20	120.68

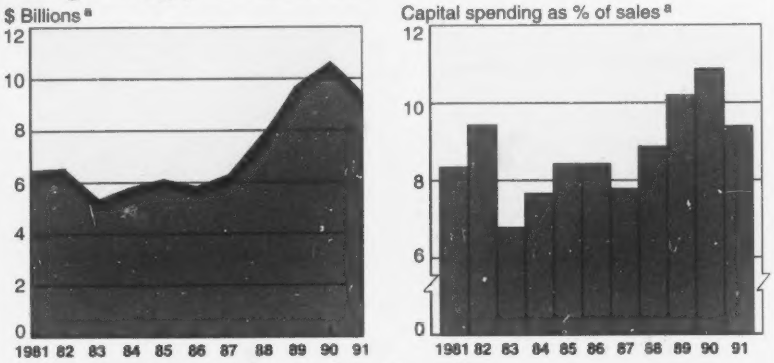
a Estimate. **Source:** Department of Commerce

Capital spending by chemical firms abroad holds on to last year's gain

$ Billions[a]	1992[b]	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982
Chemicals and allied products	$ 6.6	$ 6.5	$ 6.8	$ 5.5	$ 4.7	$ 3.7	$ 3.1	$ 2.7	$ 2.4	$ 2.3	$ 2.8
Metals, primary and fabricated	1.3	1.3	1.8	1.4	1.1	0.8	0.9	0.9	1.0	0.9	0.9
Petroleum	20.8	20.8	16.7	13.2	13.3	9.8	9.6	13.7	14.1	15.9	19.7
All manufacturing	29.6	28.2	29.4	25.3	20.4	17.2	16.4	14.9	13.6	13.6	16.8

a By majority-owned affiliates of U.S. companies. b Planned. **Source:** Department of Commerce

Chemical capital spending peaked in 1990 after rising strongly in late 1980s



a Worldwide data for 25 major chemical producers. **Source:** Company data

CHEMICAL CAPITAL SPENDING: Falls sharply for major companies in 1991

$ Millions	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981
Air Products	$ 506	$ 468	$ 414	$ 409	$ 323	$ 367	$ 392	$ 263	$ 246	$ 347	$ 323
American Cyanamid	392	376	398	374	268	263	203	200	165	171	181
Cabot[a]	213	298	233	214	83	80	184	505	80	152	194
Crompton & Knowles	11	16	13	7	4	4	3	3	2	3	7
Dow Chemical	1908	2,119	1756	1264	995	890	806	781	630	829	1176
Du Pont[b]	2045	2,045	2608	2106	1735	1357	1229	1176	989	888	1212
Ethyl	180	166	119	151	139	134	90	103	85	92	141
H. B. Fuller	30	31	41	40	30	13	15	13	15	17	10
B. F. Goodrich	219	243	240	181	143	144	202	153	115	144	205
W. R. Grace	447	514	485	418	243	199	348	380	353	560	657
Great Lakes Chemical	71	49	40	47	35	18	21	29	20	29	47
Hercules	214	273	293	251	205	257	234	218	168	174	167
Loctite	34	29	24	15	17	11	9	10	9	9	11
Lubrizol	82	77	65	55	42	41	40	30	25	52	75
Monsanto	591	750	607	590	505	520	645	614	560	673	668
Nalco Chemical	137	115	86	62	57	64	60	53	41	56	59
Olin	177	187	142	147	115	128	154	165	123	129	186
PPG Industries	335	567	671	410	499	498	452	315	450	452	376
Petrolite	22	18	19	20	19	25	24	11	9	24	15
Quaker Chemical	8	13	8	5	4	5	6	4	2	2	1
Quantum Chemical	161	459	589	334	154	102	76	116	71	66	44
Rohm & Haas	265	412	385	338	222	179	159	124	72	126	182
Stepan	34	38	34	20	26	14	19	12	10	16	12
Union Carbide	817	744	785	671	502	524	649	670	761	1179	1186
Witco	74	91	70	72	69	60	76	85	55	54	83
TOTAL	**$8973**	**$10,661**	**$9623**	**$7830**	**$6056**	**$5769**	**$6043**	**$5846**	**$4955**	**$6568**	**$6254**
ANNUAL CHANGE	**−16%**	**11%**	**23%**	**29%**	**5%**	**−5%**	**3%**	**18%**	**−25%**	**5%**	**−11%**

Note: Figures are for worldwide spending on construction, equipment, and land in consolidated businesses. Where possible, acquisition costs and investments in nonconsolidated businesses are excluded. Prior years are not restated to reflect company revisions. a Includes acquisitions and investments. b Excludes Conoco. **Source:** Company data

2 FINANCES OF THE U.S. CHEMICAL INDUSTRY

SHIPMENTS: Only drugs, soaps, toiletries had strong growth in 1991

$ Billions	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	% annual change 1990–91	% annual change 1981–91
All manufacturing industries	$2863.6	$2917.4	$2781.4	$2611.6	$2390.0	$2260.3	$2279.1	$2254.4	$2054.9	$1960.2	$2017.5	−2%	4%
Chemicals and allied products	288.0	285.6	255.5	240.5	212.7	197.1	197.3	198.2	183.2	170.7	180.5	1	5
Industrial chemicals	151.7	156.3	150.6	145.5	126.2	112.2	114.7	119.4	109.1	100.1	112.8	−3	3
Drugs, soaps, and toiletries	104.7	97.6	82.0	73.1	67.1	65.8	60.9	57.5	54.4	50.7	46.9	7	9
Petroleum and coal products	167.3	179.4	138.5	124.2	124.5	124.9	179.1	189.0	192.6	208.9	224.1	−7	-3
Rubber and plastic products	92.6	91.7	95.8	91.1	80.5	73.4	71.3	69.5	60.3	55.4	53.2	1	6
Paper and allied products	122.2	128.8	130.4	124.2	110.3	97.9	93.4	94.8	84.6	79.9	80.2	−5	4

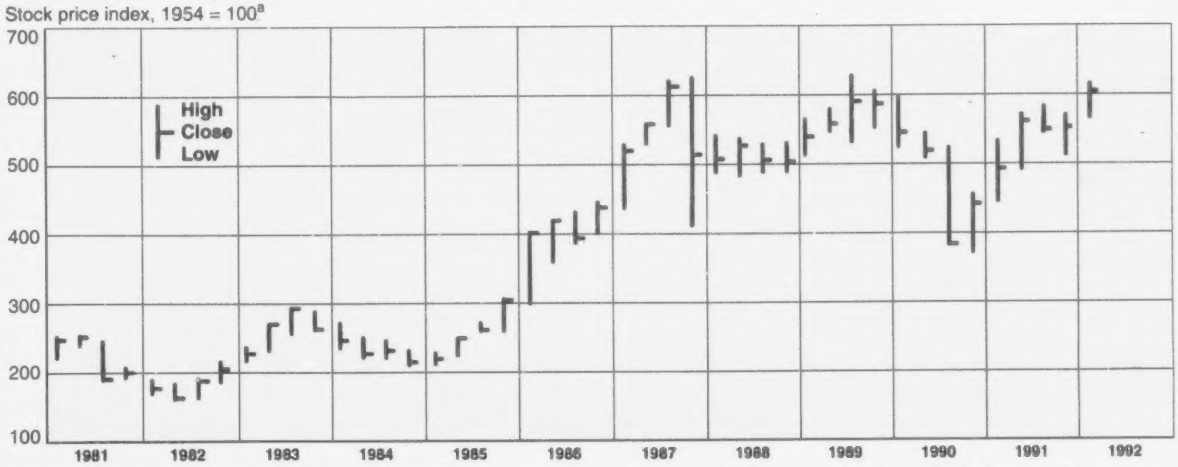
Source: Department of Commerce

PRICES: Down for industrial chemicals as well as plastic resins

Producer price indexes, 1982 = 100	Annual average 1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	% annual change 1990–91	% annual change 1981–91
All commodities	116.5	116.3	112.2	106.9	102.8	100.2	103.1	103.7	101.3	100.0	98.0	0%	2%
Industrial commodities	116.5	115.8	111.6	106.3	102.6	99.9	103.7	103.3	101.1	100.0	97.4	1	2
Finished goods	121.7	119.2	113.6	108.0	105.4	103.2	104.7	103.7	101.6	100.0	96.1	2	3
Chemicals and allied products	125.6	123.6	123.0	116.3	106.4	102.5	103.7	102.9	100.2	100.0	98.4	2	3
Industrial chemicals	111.8	113.2	114.8	106.8	95.5	91.5	96.1	96.8	97.3	100.0	103.0	−1	1
Prepared paint	129.9	124.8	119.5	112.2	108.1	107.0	105.3	103.7	100.7	100.0	95.0	4	3
Paint materials	135.8	136.3	129.1	115.7	107.3	104.4	109.5	108.2	100.3	100.0	98.5	0	3
Drugs and pharmaceuticals	182.6	170.8	160.0	148.4	139.1	129.9	122.2	114.2	107.7	100.0	92.1	7	7
Fats and oils, inedible	86.8	88.1	95.5	110.9	92.7	80.5	110.6	139.1	106.2	100.0	110.7	−1	−2
Agricultural chemicals and chemical products	111.7	107.4	108.7	104.5	96.4	94.2	96.2	97.4	96.0	100.0	97.5	−4	1
Plastic resins and materials	120.0	124.1	133.4	132.4	110.3	104.4	107.5	108.9	102.4	100.0	102.0	−3	2
Other chemicals and allied products	121.5	118.9	117.3	111.9	107.0	105.8	105.2	102.7	101.3	100.0	94.1	2	3
Rubber and plastic products	115.1	113.6	112.6	109.3	103.0	101.9	101.9	102.2	100.8	100.0	96.4	1	2

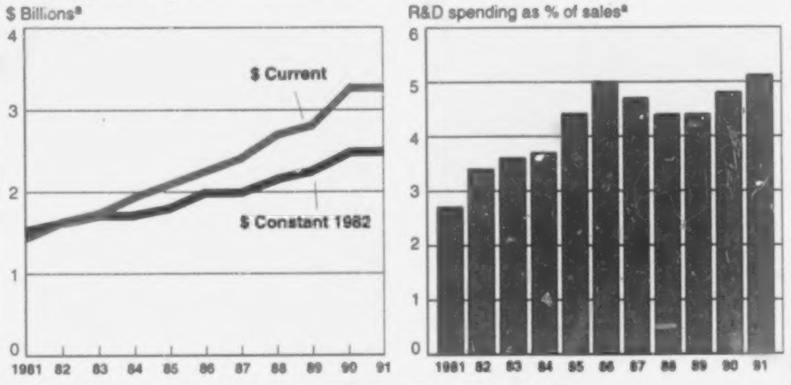
Source: Department of Labor

Chemical stock prices have been moving upward for past 18 months



[a] C&EN stock price index of American Cyanamid, Dow Chemical, W. R. Grace, Hercules, Monsanto, Rohm & Haas, and Union Carbide, weighted according to number of shares outstanding for each company.

R&D spending flat in 1991, but rose as a percentage of sales



a R&D spending by 15 major chemical producers. **Sources:** Company data, Battelle, Columbus, Ohio

R&D SPENDING: Most chemical companies reined in expenditures in 1991

$ Millions	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981
CHEMICAL COMPANIES											
Air Products[a]	$ 80	$ 72	$ 71	$ 72	$ 57	$ 61	$ 51	$ 44	$ 40	$ 37	$ 32
American Cyanamid	492	460	406	365	314	278	251	232	208	185	166
Dow Chemical	1,159	1,136	873	772	670	605	547	507	492	460	404
Ethyl	69[b]	65[b]	61[b]	59[b]	50	47	47	40	39	39	37
W. R. Grace	150	148	125	119	107	94	92	81	73	64	57
Hercules	86	92	79	74	74	71	76	72	74	74	65
International Flavors	62	57	52	50	45	39	34	32	32	31	30
Lubrizol	80	74	70	65	62	51	44	33	37	36	33
Monsanto	627	612	598	648	615	596	470	370	290	264	233
Morton International[c,d,e]	59	48	38	35	31	29	25	30	23	7	6
Nalco	47	45	41	37	35	33	32	32	30	33	30
Olin	41	66	66	58	62	56	53	52	49	45	38
Petrolite	11	12	12	12	12	12	12	12	13	10	8
Rohm & Haas	183	178	175	156	142	133	124	109	100	92	77
Union Carbide	190	191	181	159	159	148	275	265	245	240	207
TOTAL	**$ 3,336**	**$ 3,256**	**$ 2,848**	**$ 2,681**	**$ 2,435**	**$ 2,253**	**$ 2,133**	**$ 1,911**	**$1745**	**$1617**	**$1423**
ANNUAL CHANGE	**2%**	**14%**	**6%**	**10%**	**8%**	**6%**	**12%**	**10%**	**8%**	**14%**	**19%**
PHARMACEUTICAL & DIVERSIFIED COMPANIES											
Allied-Signal[c]	$ 381	$ 426	$ 381	$ 415	$ 400	$ 459	$ 343	$ 295	$ 280	$ 186	$ 152
AT&T Bell Labs	3,100	2,900	2,800	2,660	2,250	2,100	1,900	1,900	2000	2020	1590
Bristol-Myers Squibb	993	881	789	688	563	474	412	344	301	260	226
Du Pont	1,298	1,428	1,387	1,319	1,223	1,156	1,144	1,097	966	879	718
Eastman Kodak	1,494	1,329	1,253	1,147	992	1,059	976	838	746	710	615
Eli Lilly	767	703	605	512	466	427	370	341	294	267	235
FMC	135	158	150	144	132	146	149	121	102	105	94
IBM	5,001	4,419	5,201	4,419	3,998	3,975	3,457	3,148	2500	2050	1610
Merck & Co.	998	854	751	669	566	480	426	393	356	320	274
3M	914	865	784	721	650	586	520	454	396	349	306
Pfizer	757	640	531	473	401	336	287	255	230	199	179
PPG Industries	220	218	233	232	227	204	176	150	127	127	119
Procter & Gamble[d]	786	693	628	615	549	479	400	369	327	286	253
Schering-Plough	426	380	327	298	251	212	175	164	145	127	109
Upjohn	491	427	407	380	356	314	284	247	218	185	162
TOTAL	**$17,751**	**$16,321**	**$16,227**	**$14,692**	**$13,024**	**$12,407**	**$11,019**	**$10,116**	**$8988**	**$8070**	**$6642**
ANNUAL CHANGE	**9%**	**1%**	**10%**	**13%**	**5%**	**13%**	**9%**	**13%**	**11%**	**21%**	**17%**

Note: Prior years are not restated to reflect company revisions. **a** For fiscal year ending Sept. 30. **b** Adjusted to reflect spin-off of Tredegar Industries. **c** Includes all company-financed R&D but excludes contract R&D. **d** Fiscal year ends June 30. **e** Data for Morton Thiokol prior to 1985. **Source:** Company data

Explanation of company results table headings

Year. Data are for calendar year unless otherwise indicated.

Net sales. Gross sales, less discounts, allowances, and returns; generally excludes excise taxes and other operating income or revenues.

Net income. Net sales and other income, less operating costs, nonoperating charges, depreciation, depletion, interest expense, deferred charges, minority interest in income, and taxes. Nonrecurring or extraordinary credits and charges have been excluded in most cases, and are indicated by a footnote.

Total assets. Sum at year's end of current assets, investments, prepaid expenses, net plant and equipment, and other tangible assets. Excludes insofar as possible intangible assets including goodwill, value of patents, and the like.

Net plant and equipment. Value at year's end of fixed assets, less accumulated depreciation, amortization, and depletion.

Capital expenditures. Total spending during the year for new fixed assets, such as plant, equipment, and land, and for replacement and modernization of facilities.

Stockholders' equity. Equity at year's end of preferred and common stockholders, including value of capital stock, capital and earned surplus, and surplus reserves, as well as contingency and miscellaneous reserves for which no definite purpose is stated. Intangible assets are deducted insofar as possible.

Net income (breakdown). Percent of sales: net income divided by net sales. Percent of stockholders' equity: net income divided by stockholders' equity. Dollars per share: net income, less preferred dividends, divided by the number of shares of common stock outstanding. All figures are adjusted for stock splits, but no adjustment has been made for earlier years as a result of stock dividends or for dilution that might result from the conversion of preferred stock or debt to common stock or the exercise of stock options outstanding.

Dividends per share. Cash dividends paid (or declared) on each share of common stock; excludes the value of stock dividends, which are indicated by a footnote.

Dividend yield. Dividends per share divided by the average of the high and low prices of the common stock during the calendar year.

Stock price range. High-low market prices of common stock during the year, adjusted for stock splits but not for stock dividends.

Price-earnings ratio. Average of the high and low prices of the common stock during the calendar year divided by net income per share.

COMPANY RESULTS: Earnings fall for largest chemical firms, others generally profitable

(Money figures in millions of dollars unless otherwise indicated)

Year	Net sales	Net income	Total assets	Net plant and equipment	Capital expenditures	Stockholders' equity	NET INCOME			Dividend, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
							% of sales	% of stockholders' equity	$ per share				
CHEMICALS													
Air Products													
1991[a]	$2931	$248.9	$4163	$2622.6	$506.4	$1,777	8.5%	14.0%	$2.22	$0.75	2.4%	$37–25⅝	14.1
1990[a]	2895	229.9	3845	2485.1	467.5	1,634	7.9	14.1	2.07	0.69	2.7	30½–21½	12.5
1989[a]	2642	222.1	3313	2217.6	413.7	1,393	8.4	16.0	2.02	0.63	2.9	24⅜–18⅞	10.7
1988[a]	2432	213.7	2962	2061.6	386.9	1,235	8.8	17.3	1.95	0.55	2.7	26⅝–14½	10.6
American Cyanamid													
1991	$4986	$358.8	$4838	$2018.9	$392.1	$2,387	7.2%	15.0%	$3.85	$1.46	2.5%	$69–48½	15.3
1990	4570	107.8[b]	4864	1906.0	375.5	2,335	2.4	4.6	1.15[b]	1.35	2.2	61½–42	5.3
1989	4825	292.0	4720	1757.0	397.6	2,070	6.1	14.1	3.12	1.31	2.5	60⅜–45⅝	17.0
1988	4592	305.6	4332	1556.8	373.8	1,801	6.7	17.0	3.41	1.16	2.4	56–41⅞	14.4
Arco Chemical													
1991	$2837	$188.0	$3676	$2166.0	$435.0	$1,696	6.6%	11.1%	$1.96	$2.50	6.4%	$44¼–33⅛	19.7
1990	2830	308.0[c]	3739	1768.0	539.0	1,758	10.9	17.5	3.21[c]	2.50	6.8	44¼–29¾	11.5
1989	2663	405.0	2655	1263.0	262.0	1,591	15.5	25.5	4.22	2.125	6.1	40⅜–28¾	8.2
1988	2700	494.0	2548	1078.0	214.0	1,375	18.3	35.9	5.00	0.85	2.8	38–23¼	6.1
Betz Laboratories													
1991	$666	$75.5	$471	$254.6	$58.4	$254	11.3%	29.8%	$2.47	$1.16	2.3%	$62–38¾	20.4
1990	597	65.5	421	233.5	57.5	214	11.0	30.6	2.12	1.01	2.7	43¼–30¾	17.5
1989	517	55.9	359	201.5	53.0	173	10.8	32.3	1.76	0.89	3.2	31⅛–23⅝	15.5
1988	448	48.4	308	175.0	43.5	220	10.8	22.0	3.15	1.60	3.4	52½–41¼	14.9

a Fiscal year ends Sept. 30. b From continuing operations: excludes net income from discontinued operations of $245 million ($2.56 per share) but includes special net costs of $206.2 million ($2.15 per share) to curtail and consolidate product lines, reduce the carrying value of certain assets, increase environmental remediation costs, and reduce employees. c Excludes net gain from cumulative effect of change in accounting principal of $43 million ($0.45 per share).

(Money figures in millions of dollars unless otherwise indicated)

Year	Net sales	Net income	Total assets	Net plant and equipment	Capital expenditures	Stockholders' equity	NET INCOME			Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
							% of sales	% of stockholders' equity	$ per share				
Borden Chemicals & Plastics													
1991	$410	$51.6	$507	$369.2	$18.0	$293	15.7%	17.6%	$1.39[a]	$1.98[a]	17.1%	$14¾–8⅜	8.3
1990	421	45.3	544	395.8	22.1	315	10.8	14.4	1.22[a]	1.95[a]	19.0	12¾–7¾[a]	8.4
1989	466	69.5	550	417.2	28.2	342	14.9	20.3	1.87[a]	2.45[a]	14.4	24–10[a]	9.1
1988	553	121.0	605	429.3	18.9	363	21.9	33.3	3.26[a]	3.02[a]	19.5	20⅛–10⅞[a]	4.8
Cabot													
1991[b]	$1,482	$39.8[c]	$1,365	$670.4	$198.0	$329	2.7%	12.1%	$1.69	$1.04	3.3%	$35⅞–26⅝	18.5
1990[b]	1,673	71.0	1,627	878.7	174.4	466	4.2	15.2	2.73	1.04	3.3	37½–25	11.4
1989[b]	1,937	(6.5)[d,e]	1,401	743.2	192.3	472	—	—	(0.40)[d,e]	1.01	2.5	45–34⅞	—
1988[b]	1,677	61.2[f]	1,530	838.9	170.0	594	3.6	10.3	2.27[f]	0.92	2.5	48⅜–25½	16.3
Crompton & Knowles													
1991	$450	$35.9	$276	$80.2	$11.4	$108.0	8.0%	33.2%	$0.73	$0.25	1.6%	$20¼–8⅜	21.8
1990	390	30.0	252	76.7	16.4	87.0	7.7	34.5	0.61	0.195	2.1	11½–6⅝	15.0
1989	356	24.5	190	50.8	13.4	71.4	6.9	34.3	0.50	0.145	2.5	7⅞–3¾	11.6
1988	290	16.8[g]	177	43.7	7.0	53.5	5.8	31.5	0.71[g]	0.105	3.1	4½–2½	9.8
Dexter													
1991	$938	$(7.1)[d]	$721	$299.3	$61.7	$250	—	—	$(0.29)[d]	$0.88	3.9%	$26⅛–18½	—
1990	908	42.1	697	274.1	43.9	278	4.6%	15.1%	1.74	0.88	4.1	24½–18	12.2
1989	849	43.0	611	252.9	33.1	242	5.1	17.8	1.73	0.82	3.0	34¾–20⅛	15.9
1988	827	39.9[h]	541	186.9	26.1	222	4.8	18.0	1.61[h]	0.80	3.3	28¾–20¼	15.2
Dow Chemical													
1991	$18,807	$942.0	$20,418	$8,775.0	$1,908.0	$5,132	5.0%	18.4%	$3.46	$2.60	5.1%	$58–44⅛	14.8
1990	19,773	1,384.0	19,764	8,249.0	2,119.0	4,539	7.0	30.5	5.10	2.60	4.6	75¾–37	11.1
1989	17,600	2,487.0	18,169	7,642.0	1,764.0	3,960	14.1	62.8	9.20	2.18	3.4	72¼–55½	6.9
1988	16,682	2,410.0[i]	15,548	6,576.0	1,267.0	6,564	14.4	36.7	8.55[i]	1.63	2.9	62⅝–51⅛	6.7
Du Pont													
1991	$38,695	$1,403.0	$35,596	$20,610.0	$5,065.0	$16,218	3.6%	8.7%	$2.08	$1.68	4.1%	$50–32¾	19.9
1990	40,047	2,310.0	37,332	21,102.0	5,383.0	15,622	5.8	14.8	3.40	1.62	4.3	42⅜–31⅜	10.8
1989	35,534	2,480.0	33,829	18,876.0	4,285.0	14,912	7.0	16.6	3.53	1.45	4.1	42⅛–28⅝	10.0
1988	32,917	2,190.0	30,159	17,221.0	4,001.0	15,020	6.7	14.6	3.04	1.23	4.4	30⅞–25¼	9.3
Ethyl													
1991	$2,575[j]	$206.7	$7,785	$766.7	$166.1	$1,100	8.0%	18.8%	$1.75	$0.60	2.2%	$33–22¼	15.8
1990	2,514[j]	232.2	6,589	677.0	151.8	947	9.2	24.5	1.95	0.60	2.2	33–20½	13.7
1989	2,432[j]	219.0[k]	5,507	579.8	119.1	777	9.0	28.3	1.83[k]	0.51	2.0	29–21⅛	13.7
1988	2,718[j]	231.0	5,108	719.6	151.1	986	8.4	23.4	1.91	0.45	2.2	24⅛–17¼	10.8
Ferro													
1991	$1,057	$36.5[l]	$668	$234.7	$39.0	$301	3.5%	12.1%	$1.74[l]	$0.64	2.4%	$38½–15¼	15.4
1990	1,125	19.4	672	255.9	59.7	292	1.7	6.6	0.83	0.64	2.7	29⅜–17¼	28.1
1989	1,084	49.7	655	220.0	49.6	283	4.6	17.6	2.30	0.60	1.9	41⅜–22⅜	13.8
1988	1,009	46.6	575	197.2	49.3	282	4.6	16.5	2.26	0.46	2.3	27⅛–14	9.1
First Mississippi													
1991[m]	$537	$5.3	$457	$294.6	$47.2	$168	1.0%	3.2%	$0.27	$0.30	3.0%	$12⅜–7¾	37.3
1990[m]	498	4.4	497	310.0	64.6	175	0.9	2.5	0.22	0.30	1.9	19¼–11⅝	70.2
1989[m]	433	16.5	472	280.0	107.0	187	3.8	8.8	0.81	0.285	1.6	20½–14½	21.6
1988[m]	318	32.5	325	167.0	60.4	181	10.2	17.9	1.61	0.24	1.7	19⅛–9½	8.9
Freeport-McMoRan													
1991	$1,579	$41.0[n]	$3,565	$2,253.8	$804.2	$388	2.6%	10.6%	$0.57[n]	$2.50	6.7%	$31¾–43⅛	65.7
1990	1,581	283.5	3,101	2,204.5	615.7	337	17.9	84.1	4.70	2.50	7.4	30–38	7.2
1989	1,958	118.3	3,071	2,290.8	416.6	138	6.0	85.7	1.65	2.50	7.7	27⅛–38	19.7
1988	1,945	258.5	3,297	2,495.3	na	868	13.3	29.8	3.39	2.73	10.2	23⅝–29¾	7.9
Georgia Gulf													
1991	$838	$61.5	$416	$220.6	$28.3	$(358)[o]	7.3%	—	$1.75	0	—	$24¾–8⅞	9.6
1990	932	95.3	457	214.7	58.1	(424)[o]	10.2	—	3.07	0	—	11–4⅞[p]	2.6
1989	1,104	192.0	456	209.1	54.2	306	17.4	62.8%	7.58	1.00	2.1%	59⅞–36	6.3
1988	1,061	193.6	437	169.3	25.1	236	18.3	82.1	6.75	0.65	2.0	39⅞–24⅜	4.8

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a Per partnership preference unit. **b** Fiscal year ends Sept. 30. **c** From continuing operations; excludes net income from discontinued operations of $9.5 million ($0.45 per share) and net gain on disposition of discontinued operations of $77.9 million ($3.66 per share). **d** Net loss. **e** From continuing operations; includes pretax loss on restructuring of energy group of $71.7 million but excludes net gain from sale of discontinued operations of $24.6 million ($0.95 per share). **f** Excludes extraordinary net charge on early retirement of debt of $0.8 million ($0.03 per share). **g** From continuing operations; excludes net loss from operation and disposal of maintenance chemicals business of $1.5 million ($0.06 per share). **h** From continuing operations; excludes net loss from discontinued operations of $4.4 million ($0.18 per share). **i** Excludes net loss on early extinguishment of debt of $12 million ($0.04 per share). **j** Includes insurance business revenues. **k** From continuing operations; excludes income from spun-off aluminum, plastics, and energy businesses of $11.9 million ($0.10 per share). **l** Excludes restructuring charge, after taxes, of $31.7 million ($1.66 per share). **m** Fiscal year ends June 30. **n** Excludes net changes in accounting for retirement benefits of $55.7 million ($0.80 per share). **o** Deficit. **p** After recapitalization on April 27; prior to recapitalization, 45⅝–36¼. **na** = not available.

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FINANCES OF THE U.S. CHEMICAL INDUSTRY

(Money figures in millions of dollars unless otherwise indicated)

							NET INCOME						
Year	Net sales	Net income	Total assets	Net plant and equipment	Capital expenditures	Stockholders' equity	% of sales	% of stockholders' equity	$ per share	Dividend, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
B. F. Goodrich													
1991	$2472	$(80.6)[a]	$2038	$1171.0	$211.2	$ 989	—	—	$(3.50)[a]	$2.20	5.3%	$47⅝–36	—
1990	2433	115.8[b]	2198	1109.3	243.0	1200	4.8%	9.6%	4.20[b]	2.12	5.5	47⅜–29½	9.2
1989	2420	171.2[c]	2103	991.5	240.4	1117	7.1	15.3	6.23[c]	2.00	3.7	69–38½	8.6
1988	2417	209.9[d]	1987	934.4	180.5	1080	8.7	19.4	7.99[d]	1.72	3.5	60¾–37½	6.1
W. R. Grace													
1991	$6049	$219.2[e]	$5698	$2558.2	$447.0	$1744	3.6%	12.6%	$2.51[e]	$1.40	4.4%	$40¾–23⅜	12.8
1990	6754	202.8	5876	2462.1	513.7	1562	3.0	13.0	2.36	1.40	5.5	33⅝–17	10.7
1989	6115	256.6[f]	5321	2220.0	484.6	1433	4.2	17.9	3.01[f]	1.40	4.4	39⅛–25⅛	10.7
1988	5786	192.0[g]	5095	2028.3	418.1	1336	3.3	14.4	2.26[g]	1.40	5.2	29⅞–23½	11.8
Great Lakes Chemical													
1991	$1308	$157.5	$1420	$405.6	$71.2	$672	12.0%	23.4%	$2.23	$0.27	0.6%	$58–30⅜	19.8
1990	1066	140.8	1201	363.7	48.6	538	13.2	26.2	2.00	0.23	0.9	33⅞–20⅜	13.3
1989	792	122.9	935	275.9	40.5	428	15.5	28.7	1.76	0.19	1.0	24–14⅛	10.8
1988	558	103.3	612	234.4	47.0	431	18.5	24.0	1.48	0.17	1.2	16½–12⅛	9.7
Hercules													
1991	$2929	$94.9	$3467	$1476.3	$214.5	$1918	3.2%	4.9%	$2.01	$2.24	5.5%	$50⅜–31¾	20.4
1990	3200	96.0	3700	1449.9	272.6	1942	3.0	4.9	2.04	2.24	6.7	41½–25⅝	16.5
1989	3092	(96.4)[h,i]	3653	1416.5	292.6	1897	–	—	(2.09)[h,i]	2.24	4.9	52¼–38⅜	—
1988	2802	120.4	3325	1164.1	251.0	2045	4.3	5.9	2.55	2.00	4.1	54–42⅝	18.9
Imcera Group													
1991[j]	$1634	$97.2[k]	$1884	$630.2	$123.4	$718	5.9%	13.5%	$1.37[k]	$0.33	1.0%	$42⅞–22⅜	23.8
1990[j]	1425	58.9[l]	1751	585.8	85.7	445	4.1	13.2	0.84[l]	0.33	1.6	25–16	24.4
1989[j]	983	110.3[m]	1753	480.2	82.2	670	11.2	16.5	1.40[m]	0.33	2.1	18½–12⅝	11.1
1988[j]	1471	103.9[n]	1589	445.8	69.1	823	7.1	12.6	1.10[n]	0.33	2.2	17⅛–12⅜	13.4
IMC Fertilizer Group													
1991[j]	$1131	$95.8	$1739	$1220.9	$168.5	$699	8.5%	13.7%	$3.85	$1.08	2.3%	$60–33	12.1
1990[j]	1106	82.6	1585	1144.1	94.3	820	7.5	10.1	3.13	1.08	3.0	39¾–31⅛	11.3
1989[j]	1222	137.3	1678	1144.1	55.3	765	11.2	17.9	5.27	1.02	2.5	49¾–32½	7.8
1988[j,o]	1086	111.7	1472	780.0	26.3	676	10.3	16.5	3.88	0.37	1.1	45⅛–22½	8.7
International Flavors & Fragrances													
1991	$1017	$168.7	$1217	$289.6	$54.1	$960	16.6%	17.6%	$4.41	$2.40	2.8%	$104⅞–68¾	19.7
1990	963	156.7	1129	266.9	42.9	898	16.3	17.4	4.11	2.16	3.3	75⅛–54⅝	15.8
1989	870	138.6	969	236.5	34.2	765	15.9	18.1	3.65	1.92	3.0	77½–48½	17.3
1988	840	128.7	882	228.2	40.8	695	15.3	18.5	3.40	1.60	3.3	54½–43⅛	14.4
Lawter International													
1991	$153	$26.5	$178	$34.3	$8.9	$117	17.3%	22.7%	$0.61	$0.35	3.2%	$13¾–7⅞	17.7
1990	150	23.4	153	28.6	6.2	105	15.6	22.3	0.54	0.29	3.9	8½–6½	13.7
1989	136	19.5	134	24.4	3.1	88	14.3	22.2	0.45	0.29	4.1	7¾–6⅜	15.6
1988	126	20.9	125	24.5	4.5	80	16.6	26.2	0.49	0.29	4.2	7⅞–6	14.1
Loctite													
1991	$561	$71.9	$447[p]	$120.6	$33.5	$279	12.8%	25.8%	$1.98	$0.68	1.7%	$50⅛–28	19.7
1990	555	67.4	458	104.0	29.4	289	12.1	23.3	1.86	0.59	2.3	30¾–20⅝	13.8
1989	474	58.2	402[p]	82.2	23.6	260[p]	12.3	22.4	1.62	0.53	2.5	25½–16⅜	12.9
1988	439	47.6	357[p]	70.1	15.0	223[p]	10.9	21.3	1.33	0.37	2.2	19½–13½	12.4
Lubrizol													
1991	$1468	$123.7	$1154	$380.0	$82.4	$777	8.4%	15.9%	$3.57	$1.54	3.0%	$59½–44	14.5
1990	1445	127.1[q]	1097	353.6	77.4	718	8.8	17.7	3.55[q]	1.46	3.6	49–33	11.5
1989	1220	94.0	960	316.5	64.7	663	7.7	14.2	2.52	1.38	3.5	45⅛–34⅛	15.7
1988	1117	131.2[r]	971	298.7	54.6	664	11.7	19.8	3.40[r]	1.30	3.6	42⅜–30	10.6
Monsanto													
1991	$8864	$296.0[s]	$7937	$3362.0	$591.0	$2364	3.3%	12.5%	$2.33[s]	$2.045	3.4%	$76–46	26.2
1990	8995	546.0[t]	7811	3492.0	750.0	2664	6.1	20.5	4.23[t]	1.88	3.8	60⅛–38¾	11.7
1989	8681	679.0[u]	6922	3173.0	607.0	2259	7.8	30.1	5.02[u]	1.65	3.2	62⅛–40¼	10.2
1988	8293	591.0	6671	3146.0	590.0	2010	7.1	29.4	4.14	1.475	3.6	46⅛–36¾	10.0

a Net loss. **b** From continuing operations; excludes income from discontinued operations of $20.5 million ($0.25 per share). **c** From continuing operations; excludes net income from discontinued operations of $1.2 million ($0.04 per share). **d** From continuing operations; excludes net loss from discontinued operations of $12.1 million ($0.45 per share) and net gain from cumulative effect of change in accounting for income taxes of $2.7 million ($0.11 per share). **e** From continuing operations; excludes net loss from discontinued operations of $0.6 million ($0.01 per share). **f** From continuing operations; excludes net loss from discontinued operations of $3.4 million ($0.04 per share). **g** From continuing operations; excludes net income from discontinued operations and net gain from cumulative effect of accounting change of $41.6 million ($0.49 per share). **h** Net loss. **i** Excludes net gain from cumulative effect of accounting changes of $15.0 million ($0.33 per share). **j** Fiscal year ends June 30. **k** From continuing operations; excludes net loss from discontinued operations of $9.0 million ($0.38 per share). **l** From continuing operations; excludes net gain on sale of fragrance business, after taxes, of $5.2 million ($0.08 per share) and charges from environmental and litigation costs related to previously sold operations of $7.6 million ($0.12 per share). **m** From continuing operations; excludes net gain from discontinued operations of $6.7 million ($0.10 per share). **n** From continuing operations; excludes net loss on disposal of discontinued operations of $5.0 million ($0.06 per share) and extraordinary credit of $16.2 million (0.18 per share). **o** IMC Fertilizer Group, previously the fertilizer business group of International Minerals & Chemical Corp., became an independent, privately owned company on Feb. 2, 1988. **p** Not adjusted for intangible assets. **q** From continuing operations; excludes gain, after taxes, on sale of Genentech stock of $62.9 million ($1.79 per share) but includes charge for write-off of inventories and receivables due from a former affiliate of $9.7 million. **r** Includes credit for patent litigation settlement, before taxes, of $81.2 million but excludes net credit from cumulative effect of change in accounting for income taxes of $8.8 million ($0.22 per share). **s** Includes net restructuring expense of $325.0 million ($2.54 per share). **t** Includes net gain on divestitures of $56 million ($0.43 per share). **u** Includes net gain on sale of analgesics business of $36 million ($0.27 per share).

Year	Net sales	Net income	Total assets	Net plant and equipment	Capital expenditures	Stockholders' equity	NET INCOME % of sales	NET INCOME % of stockholders' equity	NET INCOME $ per share	Dividend, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
						(Money figures in millions of dollars unless otherwise indicated)							
Morton International													
1991[a]	$1906	$138.3	$1685	$722.3	$163.6	$741	7.3%	18.7%	$2.85	$0.94	1.9%	$58¼–38⅝	17.0
1990[a]	1639	129.0[b]	1448	646.2	113.3	642	7.9	20.1	2.68[b]	0.86	2.3	44¾–31½	14.2
1989[a]	1407	122.1[c]	1170	553.4	131.9	706	8.7	17.3	2.55[c]	—	—	41⅞–37½	15.6
1988[a]	1248	116.4[d]	995	478.6	97.7	606	9.3	19.2	2.43[d]	0.82[e]	2.0[e]	46–35⅝[e]	—
NL Industries													
1991	$840	($24.0)[f,g]	$1831	$738.6	$195.1	($58)[h]	—	—	$(0.40)[f,g]	$0.60	4.8%	$16¾–8½	—
1990	907	93.5[i]	1967	577.1	195.3	39	10.3%	242.4%	1.42[i]	0.60	3.5	24¾–9¼	12.0
1989	1001	170.2[j]	1512	380.5	83.4	137	17.0	124.0	2.57[j]	0.60	2.6	28–18¾	9.1
1988[k]	1007	134.2[l]	837	344.0	70.6	151	13.3	88.9	2.02[l]	0.20[m]	3.1	7¾–5¼	—
Nalco Chemical													
1991	$1237	$134.6[n]	$1186	$493.6	$136.8	$390	10.9%	34.5%	$1.78[n]	$0.83	2.4%	$42¼–26⅛	19.2
1990	1212	131.1	992	419.3	114.9	410	10.8	31.9	1.71	0.755	2.9	30⅝–22	15.4
1989	1071	119.9	892	350.9	86.4	397	11.2	30.2	1.50	0.68	3.2	25–17¼	14.3
1988	994	106.0	795	311.2	61.6	434	10.7	24.4	1.35	0.645	3.6	20–15⅝	13.2
Olin													
1991	$2275	$67.0[o]	$1880	$899.0	$177.0	$534	2.9%	12.5%	$3.32[o]	$2.20	5.0%	$54–33½	13.2
1990	2592	84.0	1760	829.0	187.0	609	3.2	13.8	4.03	2.15	4.8	60⅝–28⅛	10.7
1989	2509	124.0	1794	781.0	142.0	555	4.9	22.3	6.02	1.95	3.3	68¼–49⅜	10.2
1988	2308	98.0	1799	801.0	147.0	542	4.2	18.1	4.63	1.70	3.4	60–40	10.8
Quantum Chemical													
1991	$2532	$(123.3)[f]	$3124	$1987.2	$160.8	($278)[h]	—	—	$(4.26)[f]	$0.00	—	$19¾–9⅛	—
1990	2656	21.2	3139	2020.2	458.4	(183)[h]	0.8%	—	0.79	0.00[p]	—	31⅜–8⅛	12.7
1989	2671	114.1[q]	2910	1759.3	583.3	(266)[h]	4.3	—	4.45[q]	2.18[r]	3.3%	107⅛–28½	14.9
1988	2922	360.1[s]	2881	1308.6	333.5	(433)[h]	12.3	—	13.71[s]	2.40[t]	2.8	108¼–65½	6.3
Rohm & Haas													
1991	$2763	$163.0	$2840	$1470.0	$265.0	$1,174	5.9%	13.9%	$2.45	$1.24	3.1%	$48½–32¾	16.6
1990	2824	207.0[u]	2645	1390.0	412.0	1176	7.3	17.6	3.10[u]	1.22	4.0	37–24¼	9.9
1989	2661	176.0[v]	2361	1148.0	385.0	1217	6.6	14.5	2.65[v]	1.16	3.4	37½–31	12.9
1988	2535	230.0	2148	935.0	338.0	1113	9.1	20.7	3.46	1.02	3.1	37½–28	9.5
Sigma-Aldrich													
1991	$589	$79.8	$597	$191.7	$26.1	$441	13.5%	18.1%	$1.60	$0.23	0.6%	$53–28	25.3
1990	529	71.2	546	192.4	32.5	368	13.5	19.3	1.44	0.205	0.7	35⅜–25⅜	21.1
1989	441	64.0	472	176.4	51.7	299	14.5	21.4	1.29	0.185	0.7	29¾–21⅜	19.9
1988	375	56.5	540	119.5	35.6	244	15.0	23.2	1.15	0.165	0.7	25⅝–19⅞	19.9
Stepan													
1991	$414	$12.5	$271	$157.1	$33.7	$91	3.0%	13.8%	$2.30	$0.66	2.6%	$29¾–21⅜	11.1
1990	390	14.5	247	143.3	38.4	83	3.7	17.5	2.64	0.58	2.6	27¼–16⅝	8.3
1989	346	7.8	215	122.5	34.1	71	2.3	11.1	1.42	0.53	2.2	29½–17¾	16.6
1988	333	13.4	186	104.7	20.4	67	4.0	20.1	2.39	0.475	2.1	25⅝–19¾	9.5
Sterling Chemicals													
1991[w]	$543	$36.8	$361	$230.6	$34.4	$112	6.8%	32.8%	$0.67	$0.65	11.8%	$7⅛–3⅞	8.2
1990[w]	506	59.1	352	216.0	19.9	108	11.7	54.6	1.07	1.00	14.4	8⅝–5¼	6.5
1989[w]	581	103.9	329	216.4	57.6	110	17.9	94.1	1.77	0.75	5.9	18¾–6⅞	7.2
1988[w]	699	213.8[x]	294	172.9	17.0	91	30.6	236.1	3.56[x]	3.17	—	17¾–14⅛	4.5
Union Carbide													
1991[y]	$4877	$(116.0)[z]	$6705	$2499.0	$400.0	$2118	—	—	$(1.06)[z]	$1.00	5.3%	$22⅝–15⅛	—
1990	7621	308.0[aa]	8587	4325.0	744.0	2227	4.0%	13.8%	2.19[aa]	1.00	5.1	24⅞–14⅛	8.9
1989	8744	573.0	8483	4584.0	785.0	2320	6.6	24.7	4.07	1.00	3.6	33¼–22¾	6.9
1988	8324	662.0	8389	4416.0	671.0	1784	8.0	37.1	4.88	1.15	5.1	28⅜–17	4.6
Witco													
1991	$1631	$73.5	$1129	$474.8	$74.3	$556	4.5%	13.2%	$3.21	$1.78	4.9%	$44–28⅞	11.4
1990	1631	68.0	1136	471.0	90.8	544	4.2	12.5	2.95	1.72	5.6	39⅞–21¾	10.4
1989	1588	35.0	1121	417.2	70.4	554	2.2	6.3	1.60	1.61	4.0	45⅛–34⅝	24.9
1988	1586	71.6[bb]	1096	401.0	72.1	560	4.5	12.8	3.05[bb]	1.39	4.0	38⅜–30⅝	11.3

a Fiscal year ends June 30. **b** Excludes extraordinary net gains of $5.8 million ($0.12 per share). **c** Excludes reorganization and other extraordinary net charges of $25.0 million ($0.52 per share). **d** Excludes net charge for cumulative effect of change in accounting for income taxes of $3.8 million ($0.07 per share). **e** Data for Morton Thiokol, of which Morton International was a part until July 1, 1989. **f** Net loss. **g** Excludes extraordinary net gain of $7.5 million ($0.13 per share). **h** Deficit. **i** Excludes extraordinary net loss of $1.1 million ($0.02 per share). **j** Excludes extraordinary net gain of $2.6 million ($0.04 per share). **k** Restated to reflect restructuring and spin-off of petroleum services business on Dec. 22 (except as noted). **l** From continuing operations; excludes net income from discontinued operations of $21.5 million ($0.32 per share). **m** Before restructuring. **n** From continuing operations; excludes net income from discontinued operations of $3.2 million ($0.04 per share). **o** Excludes special charge for restructuring of operations of $80 million ($4.24 per share). **p** Paid 2% stock dividend. **q** From continuing operations; excludes net income and net gain on sale of oleochemical business of $133.3 million ($5.31 per share). **r** Plus 1% stock dividend. **s** From continuing operations; excludes net income from discontinued oleochemical business of $22.6 million ($0.86 per share). **t** Excludes special dividend declared of $50.00 per share. **u** Includes net gain on sale of surfactant and alkylphenol businesses of $26 million ($0.39 per share), on sale of forest property of $20 million ($0.20 per share), and net loss for write-off of intangible assets in electronic materials business of $187 million ($0.27 per share). **v** Includes net gain on sale of interest in U.K. subsidiary of $15 million ($0.23 per share). **w** Fiscal year ends Sept. 30. **x** Excludes net loss on early extinguishment of debt of $9.0 million ($0.15 per share) and net gain on cumulative effect of change in accounting for income taxes of $8.3 million ($0.14 per share). **y** Excludes industrial gases business, to be spun off during 1992. **z** Net loss. **aa** Includes net loss from sale of 50% interest in carbon product business of $86 million ($0.61 per share) and net gain from sale of other businesses of $80 million ($0.57 per share). **bb** Excludes net gain on cumulative effect of accounting change of $20.3 million ($0.81 per share).

2 FINANCES OF THE U.S. CHEMICAL INDUSTRY

(Money figures in millions of dollars unless otherwise indicated)

Year	Net sales	Net income	Total assets	Net plant and equipment	Capital expenditures	Stockholders' equity	NET INCOME			Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
							% of sales	% of stockholders' equity	$ per share				
PHARMACEUTICALS													
Abbott Laboratories													
1991	$6,877	$1088.7[a]	$6,255	$2662.1	$770.6	$3203	15.8%	34.0%	$1.28[a]	$0.50	1.8%	$34¾–19⅝	21.3
1990	6,159	965.8	5,563	2375.8	641.4	2834	15.7	34.1	1.11	0.42	2.2	23¼–15⅝	17.5
1989	5,380	859.8	4,852	2090.2	573.1	2726	16.0	31.5	0.96	0.35	2.4	17½–11½	15.1
1988	4,937	752.0	4,825	1952.6	521.2	2465	15.2	30.5	0.84	0.30	2.5	13–10⅝	14.3
American Home Products													
1991	$7,079	$1375.3	$5,684	$1476.8	$227.9	$3046	19.4%	45.2%	$4.36	$2.375	3.6%	$86¼–47⅛	15.3
1990	6,775	1230.6[b]	5,354	1437.4	247.7	2392	18.2	51.4	3.92[b]	2.15	4.3	55–44	12.6
1989	6,747	1102.2	5,114	1481.7	250.7	1403	16.3	78.6	3.54	1.95	4.1	54½–40⅛	13.4
1988	5,501	932.2	3,967	1309.3	344.5	2332	16.9	40.0	3.19	1.80	4.6	42⅛–35½	12.2
Bristol-Myers Squibb													
1991	$11,159	$2056.0	$9,246	$2936.0	$633.0	$5625	18.4%	36.6%	$3.95	$2.40	3.2%	$89⅜–61⅛	19.1
1990	10,300	1748.0	9,023	2631.0	526.0	5226	17.0	33.4	3.33	2.12	3.6	68–50½	17.8
1989	9,189	747.0[c]	8,273	2350.0	562.0	4860	8.1	15.4	1.43[c]	2.00	3.9	58–44	35.7
1988	8,558	1254.0	8,045	2188.0	471.0	4720	14.7	26.6	2.39	1.68[d]	4.0[d]	46½–38⅛[d]	14.7[d]
Johnson & Johnson													
1991	$12,447	$1461.0	$10,513	$3667.0	$987.0	$5626	11.7%	26.0%	$4.39	$1.54	1.7%	$116¼–65⅜	20.7
1990	11,232	1143.0[e]	9,506	3247.0	830.0	4900	10.2	23.3	3.43[e]	1.31	2.1	74⅛–51⅛	18.3
1989	9,757	1082.0	7,919	2846.0	750.0	4148	11.1	26.1	3.25	1.12	2.2	59½–41½	15.5
1988	9,000	974.0	7,119	2493.0	664.0	3503	10.8	27.8	2.86	0.96	2.4	44–34⅝	13.7
Eli Lilly													
1991	$5,726	$1314.7	$7,873	$3782.5	$1,142.4	$4540	23.0%	29.0%	$4.50	$2.00	2.6%	$84⅞–69	17.1
1990	5,192	1127.3	6,674	2936.7	1,007.3	2998	21.7	37.6	3.90	1.64	2.2	89¾–59⅜	19.1
1989	4,176	939.5	5,394	2114.6	554.5	3303	22.5	28.4	3.20	1.35	2.4	68½–42⅜	17.3
1988	3,607	761.0	4,853	1806.6	372.1	2815	21.1	27.0	2.67	1.15	2.8	45¾–35½	15.3
Merck													
1991	$8,603	$2121.7	$9,349	$3504.5	$1,041.5	$4767	24.7%	44.5%	$1.83	$0.77	1.9%	$55⅝–27⅜	22.7
1990	7,671	1781.2	7,873	2721.7	670.8	3677	23.3	48.4	1.52	0.64	2.4	30⅜–22⅜	17.3
1989	6,550	1495.4	6,593	2292.5	433.0	3357	22.8	44.5	1.26	0.55	2.4	26⅞–18¾	18.1
1988	5,939	1206.8	5,992	2070.7	372.7	2720	20.3	44.4	1.02	0.43	2.4	19⅞–16	17.6
Pfizer													
1991	$6,950	$917.1[f]	$9,251	$2381.0	$593.8	$4643	13.2%	19.8%	$2.71[f]	$1.32	2.1%	$86⅛–36¾	22.7
1990	6,406	801.2	8,553	2109.8	547.5	4593	12.5	17.4	2.38	1.20	3.5	40⅞–27¼	14.3
1989	5,671	681.1	7,895	1784.1	456.5	4106	12.0	16.6	2.02	1.10	3.4	37⅞–27	16.1
1988	5,385	791.3	7,218	1655.1	343.7	3882	14.7	20.4	2.35	1.00	3.7	30⅛–23¾	11.4
Schering-Plough													
1991	$3,616	$645.6	$3,822	$1490.4	$339.4	$1155	17.9%	55.9%	$3.01	$1.27	2.4%	$67⅛–40¾	17.9
1990	3,323	565.1	3,937	1284.4	242.9	1915	17.0	29.5	2.50	1.065	2.4	50¾–37	17.6
1989	3,158	471.3	3,440	1210.7	186.1	1782	14.9	26.4	2.09	0.875	2.5	43–27⅝	16.9
1988	2,969	389.9	3,234	1181.0	156.1	1486	13.1	26.2	1.74	0.70	2.7	29⅝–22⅝	15.0
Upjohn													
1991	$3,402	$537.4	$4,147	$1540.7	$258.1	$2005	15.8%	26.8%	$2.96	$1.26	3.0%	$49¼–34¾	14.2
1990	3,021	458.1[g]	3,668	1421.6	246.8	1780	15.2	25.7	2.48[g]	1.04	2.7	44⅝–33	15.7
1989	2,725	323.6[h]	3,232	1275.1	242.3	1736	11.9	18.6	1.74[h]	0.94	2.7	42⅛–27⅝	21.8
1988	2,746	368.7[i]	3,139	1239.6	241.0	1821	12.9	19.4	1.97[i]	0.80	2.6	35¼–26⅞	15.8
Warner-Lambert													
1991	$5,059	$452.8[j]	$3,444	$1350.0	$326.0	$1013	9.0%	44.7%	$4.16[j]	$1.76	2.4%	$82¼–61¾	17.3
1990	4,687	484.9	3,100	1301.4	239.9	1241	10.3	39.1	3.61	1.52	2.5	70⅜–49⅝	16.6
1989	4,196	412.7	2,720	1132.5	218.5	990	9.8	41.7	3.05	1.28	2.6	59⅜–37¼	15.8
1988	3,908	340.3	2,554	1053.0	189.6	850	8.7	40.0	2.50	1.08	3.1	39¾–30	13.9

[a] Excludes extraordinary net gain on sale of investment in Amgen of $128.2 million ($0.15 per share). [b] Includes gain on sale of household products and depilatory businesses, before taxes, of $999.5 million. [c] Includes charges and expenses for integrating operations of Bristol-Myers Co. and Squibb Corp., after taxes, of $693 million ($1.32 per share). [d] For Bristol-Myers Co. only. [e] Includes charge for damage to operations in Latin America of $125 million ($0.38 per share). [f] Excludes special charge for projected payments in connection with potential future Shiley C/C heart valve fractures of $195 million ($0.58 per share). [g] From continuing operations; excludes loss on discontinued operations and their disposal of $2.4 million ($0.01 per share) but includes partial pension settlement net gain of $37.8 million. [h] From continuing operations; includes restructuring and other nonrecurring charges of $57.3 million but excludes net loss of discontinued operations and their disposal of $147.6 million ($0.79 per share). [i] From continuing operations; excludes loss from discontinued operations of $15.3 million ($0.08 per share). [j] Excludes nonrecurring net charges for restructuring of $418.0 million ($3.11 per share) and for cumulative effect of accounting change of $106.0 million ($0.79 per share).

3 EMPLOYMENT IN THE U.S. CHEMICAL INDUSTRY

Chemical employment declined in 1991

In 1991 the recession took its toll on chemical industry employment. After four years of uninterrupted growth, overall employment in the chemicals and allied products industry eased off 1% to an average level for the year of 1.07 million workers. The decline was more severe for all manufacturing, where employment fell 3%, according to the Department of Labor.

Some sectors of the chemical industry were particularly hard hit. Employment in industrial inorganic chemical firms dropped 9% to 126,000 workers. Also hurt by the recession were paint and allied products employees, whose numbers declined 5% to 58,000. Workers in plastics materials and synthetics; soaps, cleaners, and toilet goods; and miscellaneous chemical products each experienced a 2% decline in their numbers. Only the work force of pharmaceutical companies grew last year, by 3% to 245,000.

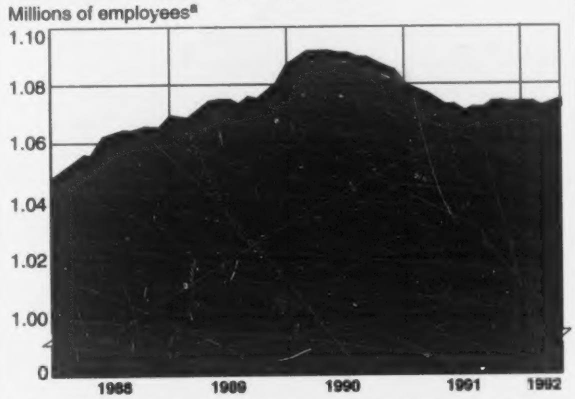
A look at the Labor Department's monthly data shows that chemical industry employment actually began to fall off about two years ago. The employment cycle peaked in spring 1990 at a seasonally adjusted level of 1.09 million employees. It had dropped to 1.07 million by March 1991 and was still holding steady at that level when the most recent data were collected last month.

Production workers were somewhat harder hit by job losses in the chemical industry than were workers in other parts of the industry. Overall, they posted a 4% loss of jobs in 1991, following a 1% drop in 1990.

As of January 1991, employment of scientists and engineers in the chemical industry was still holding firm. Nearly 80,000 scientists and engineers were working in R&D in the chemical industry then, a 1% rise over January 1990. Drug companies, which employ 43% of the industry's R&D scientists and engineers, had increased their employment by 3% from a year earlier. But employment at industrial chemical firms was up as well, by 1% to 22,300 people.

C&EN's company-by-company compilation of employment at some of the largest chemical companies saw a 3% drop in employment in 1991, following a 2% loss in 1990. Because sales declined for these companies along with employment, sales per employee remained unchanged.

Number of workers in chemical industry has eased from 1990 peak



a Seasonally adjusted employment in U.S. chemicals and allied products industry; April and May 1992 figures are preliminary. **Source:** Department of Labor

INDUSTRIAL EMPLOYMENT: Many chemical industry sectors lost jobs last year

Thousands	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	% annual change 1990–91	% annual change 1981–91
All manufacturing	18,455	19,117	19,442	19,350	19,024	18,965	19,260	19,378	18,434	18,781	20,170	−3%	−1%
Chemicals and allied products	1,072	1,088	1,076	1,059	1,026	1,022	1,044	1,049	1,043	1,075	1,109	−1	0
Industrial inorganic chemicals	126	138	135	133	131	135	143	143	151	161	162	−9	−2
Plastics materials and synthetics	177	181	182	177	168	168	172	178	177	185	196	−2	−1
Drugs	245	237	232	228	215	208	206	206	201	199	199	3	−2
Soap, cleaners, and toilet goods	156	160	161	160	153	147	148	146	142	144	146	−2	1
Paints and allied products	58	61	63	63	63	63	64	62	60	60	63	−5	−1
Industrial organic chemicals	155	155	150	146	148	154	160	162	163	171	178	0	−3
Agricultural chemicals	56	56	54	52	51	54	59	61	61	65	70	0	−2
Miscellaneous chemical products	98	100	100	101	97	94	94	92	89	91	94	−2	0
Petroleum and coal products	159	158	156	160	164	169	179	189	196	201	214	1	−2
Rubber and miscellaneous plastics products	864	890	891	868	843	823	819	814	743	729	772	−3	1

Note: Average annual domestic employment. **Source:** Department of Labor

3 EMPLOYMENT IN THE U.S. CHEMICAL INDUSTRY

PRODUCTION WORKERS: Industrial chemicals and plastics had biggest work force declines

Thousands[a]	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	% annual change 1990–91	1981–91
All manufacturing	12,467	12,979	13,269	13,254	12,970	12,877	13,092	13,285	12,530	12,742	14,020	−4%	−2%
Chemicals and allied products	579	601	605	597	575	568	578	583	579	599	628	−4	−1
Industrial inorganic chemicals	62	70	70	69	67	69	72	73	77	86	88	−11	−3
Plastics materials and synthetics	110	116	119	116	111	113	114	117	115	119	130	−5	−1
Drugs	108	105	102	101	99	96	95	96	98	98	99	3	1
Soap, cleaners, and toilet goods	96	99	101	103	98	93	94	93	89	90	92	−3	1
Paints and allied products	30	31	32	31	31	30	31	30	29	29	31	−3	0
Industrial organic chemicals	81	86	88	86	83	81	82	82	84	86	90	−6	−1
Agricultural chemicals	34	34	34	33	32	33	37	38	37	40	44	0	−2
Miscellaneous chemical products	58	59	59	58	55	53	54	54	51	51	54	−2	1
Petroleum and coal products	102	103	102	104	107	106	109	111	118	120	134	−1	−2
Rubber and miscellaneous plastics products	663	689	694	675	654	639	632	633	574	558	597	−4	1

a Average annual domestic employment. **Source:** Department of Labor

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EMPLOYMENT OF WOMEN: Growing fastest at industrial inorganic chemical makers

	1990[a]		1980[a]	
	(thousands)	% of total	(thousands)	% of total
All manufacturing	6297.0	33%	6317.0	31%
Chemicals and allied products	329.2	30	277.3	25
Industrial inorganic chemicals	29.9	21	23.9	15
Plastics materials and synthetics	41.4	23	43.9	21
Drugs	106.7	45	82.0	42
Soap, cleaners, and toilet goods	72.5	45	57.3	41
Paints and allied products	12.6	20	12.5	19
Industrial organic chemicals	31.1	20	26.3	15
Agricultural chemicals	9.1	16	10.7	15
Miscellaneous chemical products	26.0	26	20.7	22
Petroleum and coal products	25.8	16	27.0	14
Rubber and miscellaneous plastics products	312.0	35	251.0	33

a Average annual domestic employment. **Source:** Department of Labor

WORKWEEK: Longer for chemical workers, shorter in other fields

Hours[a]	1991	1990	1989
All manufacturing	40.7	40.8	41.0
Chemicals and allied products	42.9	42.6	42.4
Industrial inorganic chemicals	43.6	42.9	42.7
Plastics materials and synthetics	42.6	42.5	43.1
Drugs	42.5	41.8	41.7
Soap, cleaners, and toilet goods	40.9	40.8	40.1
Paints and allied products	41.8	41.9	41.8
Industrial organic chemicals	45.6	45.2	44.6
Agricultural chemicals	44.4	44.1	43.4
Miscellaneous chemical products	42.3	42.4	42.4
Petroleum and coal products	44.1	44.6	44.3
Rubber and miscellaneous plastics products	41.1	41.1	41.4

a For production workers in domestic employment. **Source:** Department of Labor

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EMPLOYMENT OF SCIENTISTS, ENGINEERS: Continues to rise in chemical industry

Thousands[a]	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981
Total, all industry	709.7	730.9	720.2	708.6	695.8	671.0	622.5	584.1	540.9	509.8	487.8
Chemicals and allied products	79.9	78.9	77.6	75.8	75.2	75.8	71.1	69.8	67.3	61.6	54.7
Drugs and medicines	34.5	33.5	34.0	33.0	32.6	31.8	30.8	30.8[b]	28.2	25.6	23.3
Industrial chemicals	23.3[b]	23.0[b]	23.1[b]	22.5[b]	22.4[b]	24.9	23.5	25.6	26.6	25.9	21.6
Other chemicals	22.1	22.4	20.5	20.3	20.2	19.1	16.7	13.4	12.1	10.1	9.8
Petroleum refining and extraction	10.0	10.2	10.3	9.5	9.9	10.4	13.5	13.3	14.7	15.6	13.0

a Full-time equivalent number of R&D scientists and engineers in industry, as of January of each year. b Partly estimated. **Source:** National Science Foundation

CHEMICAL EMPLOYMENT: Drops to lowest level in decade at major companies

Thousands	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981
Air Products	14.6	14.0	14.1	13.3	12.1	16.6	18.7	17.7	16.7	18.9	16.2
American Cyanamid	31.6	32.0	35.4	35.5	34.3	34.5	36.4	38.2	38.7	40.2	41.8
Betz Laboratories	4.0	3.7	3.4	3.1	2.0	2.6	2.5	2.5	2.3	2.2	2.2
Cabot	5.3	6.0	5.5	5.2	5.1	6.6	7.7	7.5	7.2	7.5	7.7
Crompton & Knowles	2.0	1.8	1.7	1.6	1.3	1.3	2.3	2.3	2.4	2.3	2.5
Dow Chemical	62.2	62.1	62.1	55.5	53.1	51.3	53.2	49.8	54.5	56.6	63.8
Ethyl	6.0	5.7	5.5	10.4	10.0	10.5	10.5	11.0	13.0	14.0	14.5
H. B. Fuller	5.6	5.6	5.5	5.2	4.6	4.5	4.4	4.3	4.1	4.0	3.3
B. F. Goodrich	14.4	14.7	11.9	12.3	12.0	11.9	26.2	28.8	29.4	30.0	33.7
W. R. Grace	46.6	49.0	46.4	45.7	39.4	41.4	116.9	102.6	95.5	82.2	89.0
Hercules	17.3	19.9	23.3	22.7	23.2	25.1	25.4	26.3	24.2	24.5	25.9
Imcera Group	9.8	9.6	6.9	6.9	12.9	13.9	8.7	9.0	8.4	8.4	10.6
International Flavors	4.2	4.2	4.2	4.2	4.1	3.8	3.7	3.7	3.7	3.6	3.6
Lubrizol	5.3	5.2	5.3	4.8	4.8	4.8	5.2	4.2	4.2	4.3	4.2
Monsanto	39.3	41.1	42.2	45.6	49.7	51.7	56.1	50.8	48.8	52.2	57.4
Nalco Chemical	6.8	5.9	5.5	5.4	5.1	4.9	5.1	4.8	4.6	4.6	4.7
Olin	14.4	15.2	15.4	16.4	14.1	13.2	14.9	17.8	18.2	17.5	20.3
PPG Industries	33.7	35.1	35.5	36.3	36.8	36.5	37.5	37.7	37.0	37.0	36.6
Rohm & Haas	12.9	12.9	13.0	12.4	12.0	12.1	11.8	11.9	11.4	11.5	13.5
Stepan	1.3	1.3	1.2	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9
Union Carbide	36.7	38.8	46.0	44.0	43.1	50.3	91.5	98.4	99.5	103.2	110.3
TOTAL EMPLOYEES	**374.0**	**383.8**	**390.0**	**387.5**	**380.7**	**398.4**	**539.6**	**530.2**	**524.7**	**525.6**	**562.7**
ANNUAL CHANGE	**−2.6%**	**−1.6%**	**0.6%**	**1.8%**	**−4.4%**	**−26.2%**	**1.8%**	**1.0%**	**−0.2%**	**−6.6%**	**−2.5%**
SALES PER EMPLOYEE ($ thousands, current)	**$205.6**	**$206.1**	**$193.6**	**$186.7**	**$163.8**	**$ 138.6**	**$108.7**	**116.4**	**$111.0**	**$108.9**	**$110.7**
SALES PER EMPLOYEE ($ thousands, constant 1982[a])	**$167.2**	**$166.7**	**$157.4**	**$160.6**	**$154.0**	**$ 135.1**	**$104.8**	**$113.1**	**$110.7**	**$108.9**	**$112.5**

Note: Data are not restated for acquisitions, divestitures, or similar developments. a Based on producer price index for chemicals and allied products. **Source:** Company data

WAGES: Rising faster for chemical workers than for workers in other manufacturing areas

	Hourly earnings[a]				Weekly earnings[a]			
	1991	1990	1989	1988	1991	1990	1989	1988
All manufacturing	$11.18	$10.84	$10.47	$10.18	$455.03	$442.27	$429.27	$417.99
Chemicals and allied products	14.07	13.54	13.09	$12.71	603.60	576.80	555.02	536.36
Industrial inorganic chemicals	15.16	14.67	14.19	13.83	660.98	629.34	605.91	590.54
Plastics materials and synthetics	14.81	14.02	13.44	13.06	630.91	595.85	579.26	566.80
Drugs	13.54	12.87	12.51	12.07	575.45	537.97	521.67	496.08
Soap, cleaners, and toilet goods	12.05	11.76	11.28	11.05	492.85	479.81	452.33	444.21
Paints and allied products	12.57	12.01	11.66	11.24	525.43	503.22	484.39	470.96
Industrial organic chemicals	16.54	15.97	15.65	15.30	754.22	721.84	697.99	670.14
Agricultural chemicals	14.18	13.58	12.79	12.35	629.59	598.88	555.09	534.76
Miscellaneous chemical products	12.61	12.30	11.92	11.54	533.40	521.52	505.41	485.83
Petroleum and coal products	17.02	16.23	15.41	14.97	750.58	723.86	682.66	664.67
Rubber and miscellaneous plastics products	10.10	9.79	9.47	9.19	415.11	402.37	392.06	383.22

a For production workers in domestic employment. **Source:** Department of Labor

Smaller work force leads to productivity gains

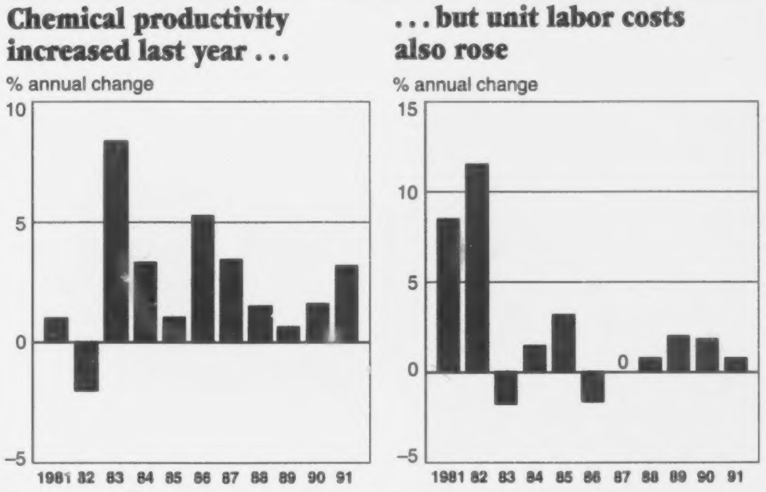
Productivity in the chemicals and allied products industry improved last year, with this measure of industry health showing its biggest increase in four years. However, unit labor costs also increased as wages for production workers rose faster than output, providing a discordant note to an otherwise moderately good performance. Productivity is measured as output per workhour. Unit labor cost is the cost of labor (wages) per unit of output.

In 1991, productivity for the chemicals and allied products industry increased 3.1%. The gain came, not through a big increase in production, but rather by a decline in workhours within the industry. Production grew just 0.7%, but workhours for production workers declined 2.3% as chemical producers cut employment.

Chemical productivity grew more than productivity for the all-manufacturing category, which is all types of manufacturing industries in the U.S. including the chemical industry. For this umbrella group of all industries, output per workhour rose just 2.1% last year. Unlike chemicals, however, both output and workhours declined for all manufacturing. Production fell 2.1%, and production workhours declined 4.2%.

The bad news for chemicals, and indeed for all manufacturing as well, is that while productivity was increasing, so were unit labor costs, which ideally should decline as productivity rises. However, hourly production wages for chemical workers rose 3.8% in 1991, but productivity increased a slower 3.1%. The effect was a rise of 0.8% in the cost of producing each unit of product. The best news that can be derived from this is that it represents the lowest increase in three years.

Nonetheless, the chemical industry controlled its productivity better in 1991 than it did the year before. The 3.1% rise in productivity last year is almost twice that of 1990, when output per workhour rose just 1.6% from the previous year. And the 0.8% increase in unit labor costs in 1991 is less than half the 1.9% increase in 1990.



Sources: Federal Reserve Board, Department of Labor, C&EN estimates

PRODUCTIVITY: Shorter workhours made chemical industry more productive in 1991

Indexes, 1987 = 100	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981
CHEMICALS AND ALLIED PRODUCTS											
Production	110.9	110.1	108.5	105.4	100.0	94.6	91.4	91.4	87.5	81.8	89.2
Workhours	103.0	105.4	105.4	103.8	100.0	97.8	99.4	100.3	99.2	100.5	107.4
Productivity[a]	107.7	104.5	102.9	101.5	100.0	96.7	92.0	91.1	88.2	81.4	83.1
Hourly production wages	113.7	109.5	105.8	102.3	100.0	96.7	93.6	89.8	85.7	80.6	73.7
Unit labor costs[b]	105.6	104.8	102.8	100.8	100.0	100.0	101.7	98.6	97.2	99.0	88.7
ALL MANUFACTURING											
Production	107.5	109.9	108.9	105.8	100.0	94.3	91.6	89.3	80.9	76.6	80.3
Workhours	95.2	99.4	102.2	102.9	100.0	98.5	99.7	101.5	94.4	93.1	104.8
Productivity[a]	112.9	110.6	106.6	102.8	100.0	95.7	91.9	88.0	85.7	82.8	76.6
Hourly production wages	112.8	109.3	106.1	102.9	100.0	98.3	95.9	92.8	89.3	86.0	80.9
Unit labor costs[b]	100.0	98.8	99.5	100.1	100.0	102.7	104.3	105.4	104.2	103.9	105.6

a Productivity is output per workhour, calculated by dividing indexes for production by indexes for workhours of production employees. **b** Unit labor costs are labor costs per unit of output, calculated by dividing indexes for wages by indexes for output per workhour. **Sources:** Federal Reserve Board, Department of Labor, C&EN estimates

Recession dampened chemical markets

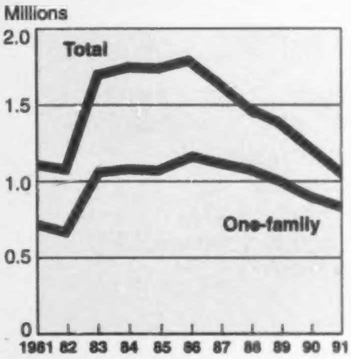
Markets for chemicals were not immune to the general downturn in the economy during 1990 and 1991. As these two pages graphically show, many of the key markets for chemicals and allied products declined last year. And for several of the most important ones, this downturn was only a continuation of a falloff that began several years earlier.

With the economy as a whole in recession, it's not surprising that chemical manufacturers, whose output finds its way into such a vast array of final products, have been affected. The gross national product edged up a mere 3% in 1991, about 1% less than the inflation rate. Personal consumption, which is the ultimate market for much of the chemical industry, did only slightly better—it managed to just keep pace with inflation for the year.

Some of the chemical industry's most important markets did much worse than that. New housing—a major market for plastics, synthetic fibers, and coatings—dropped to its lowest level in a decade in its fifth straight year of decline. Housing starts fell 15% last year to only 55% of what they were in 1986. Sales of U.S.-made automobiles—another major market for coatings, plastics, and rubber chemicals—declined 11% last year, so that only two cars were made in the U.S. last year for every three that were made here in 1985.

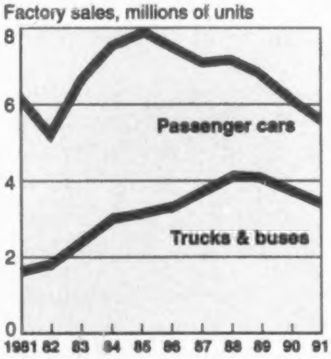
Of the markets presented here, only two—plastics products and paper and paperboard—grew at all last year. And even for these, growth was well below their performance through much of the 1980s.

Housing starts



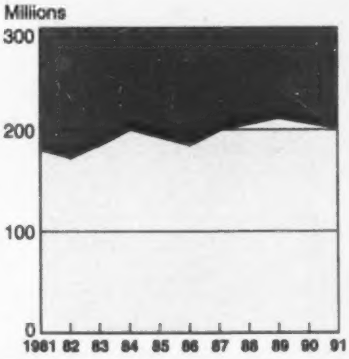
Source: Bureau of the Census

Motor vehicles



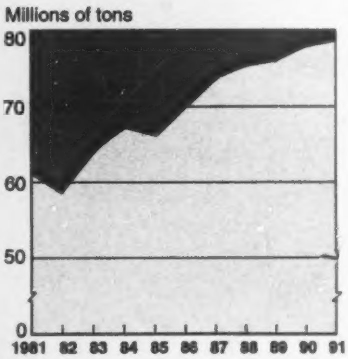
Source: Motor Vehicle Manufacturers Association

Tires and tubes



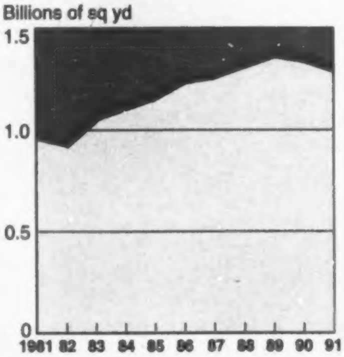
Source: Rubber Manufacturers Association

Paper and paperboard



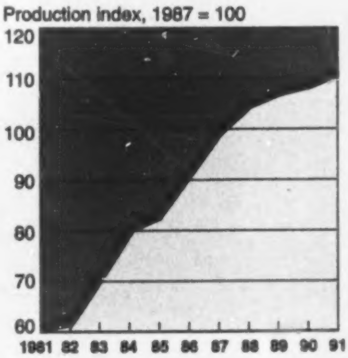
Source: American Paper Institute

Floor coverings



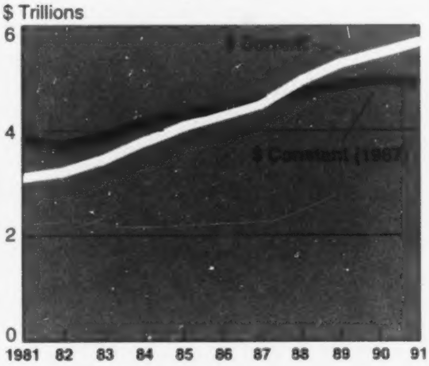
Source: Bureau of the Census

Plastics products



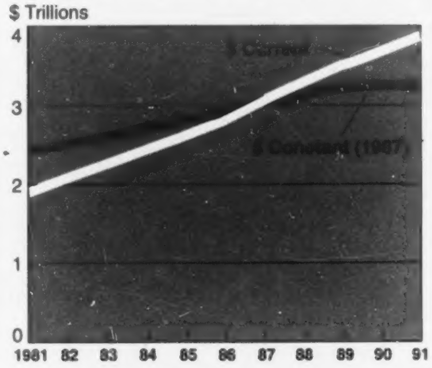
Source: Federal Reserve Board

Gross national product



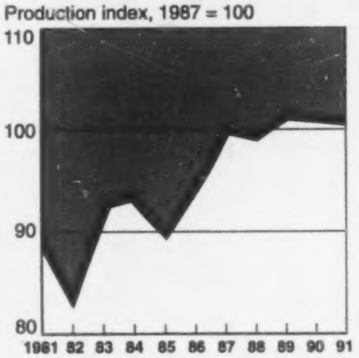
Source: Department of Commerce

Personal consumption expenditures



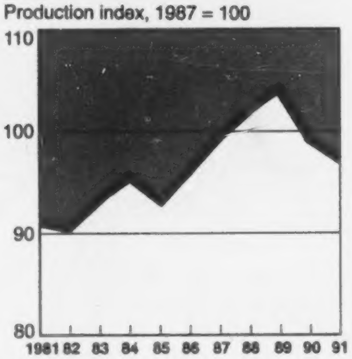
Source: Department of Commerce

Textile mill products



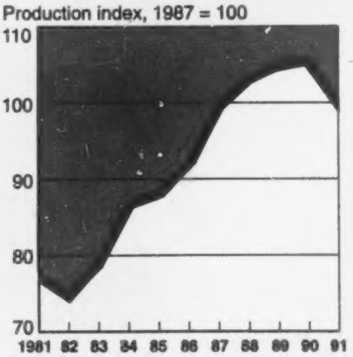
Source: Federal Reserve Board

Apparel



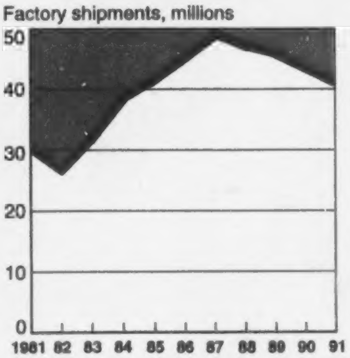
Source: Federal Reserve Board

Furniture and fixtures



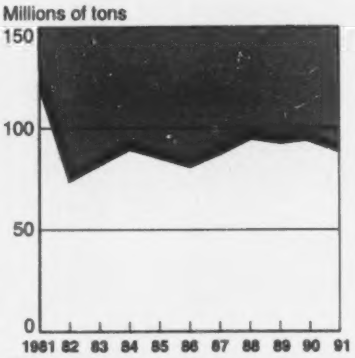
Source: Federal Reserve Board

Major home electrical appliances



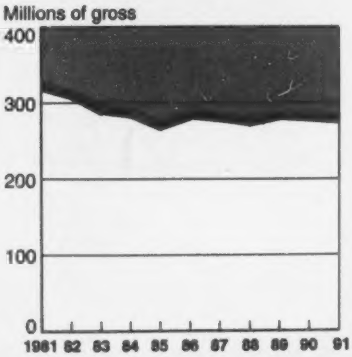
Source: Association of Home Appliance Manufacturers

Steel



Source: American Iron & Steel Institute

Glass containers



Source: Bureau of the Census

5 FOREIGN TRADE

U.S. chemical trade posts banner year

What can we do for an encore? That's the big question on the minds of many U.S. chemical traders after the excellent performance they turned in last year. In fact, 1991 was an excellent year for all U.S. trade, not just chemicals.

Total U.S. exports jumped 7% to $422 billion. Meanwhile, imports actually declined—something they haven't done since the recession in 1982. And the overall trade deficit ($66 billion) dropped below the $100 billion mark for the first time since 1983.

But as impressive as these overall trade figures are, they pale by comparison to last year's chemical trade performance. Chemical exports climbed 10% to almost $43 billion—the sixth successive record high. Chemical imports also set a new record last year, increasing 8% to $24.2 billion.

But that export-import combination pushed the chemical trade surplus to an all-time high of $18.8 billion and marked 1991 as the sixth year in a row that the chemical trade surplus established a new record. Only the $27 billion trade surplus of aircraft manufacturers topped the chemical trade surplus last year.

Putting the chemical industry's trade performance in perspective, it has chalked up a cumulative surplus of more than $138 billion since 1980, despite recessions and periods when the dollar was strong, which hurt exports. During the same period, overall U.S. trade has accumulated a deficit of more than $1 trillion. It has not enjoyed a single year in which it had a surplus during that time.

With the understandable exception of the former East European bloc, U.S. chemical exports last year were strong to all areas of the world. As a result, the U.S. share of world chemical exports jumped a full percentage point—to 15%. But there are signs that the chemical trade surplus may be topping out. During the last few months of 1991 and the first few months of this year, the chemical trade balance has been slipping a little.

U.S. TOTAL TRADE BALANCE: Trade deficit drops sharply

$ Billions	1991	1990	1989	1988	% annual change 1990–91
Total exports	$ 421.9	$ 394.0	$ 364.3	$ 322.4	7%
Total imports	488.1	495.0	472.9	440.9	–1
Trade balance	–66.2	–101.0	–108.6	–118.5	–35

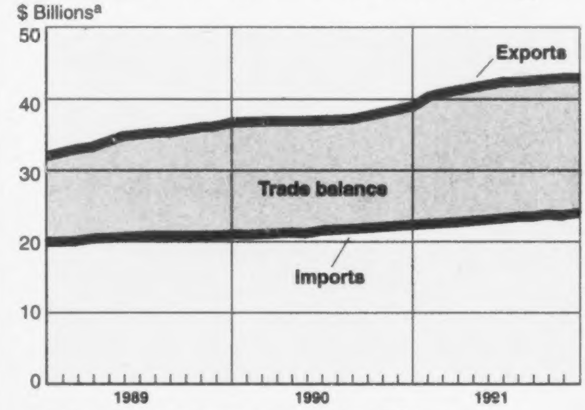
Source: Department of Commerce

U.S. CHEMICAL TRADE BALANCE: Chemical surplus sets another record

$ Millions	1991	1990	1989	1988	% annual change 1990–91
Chemical exports	$42,967	$38,983	$36,485	$31,909	10%
Chemical imports	24,169	22,468	20,752	20,326	8
Chemical trade balance	18,798	16,515	15,733	11,583	14

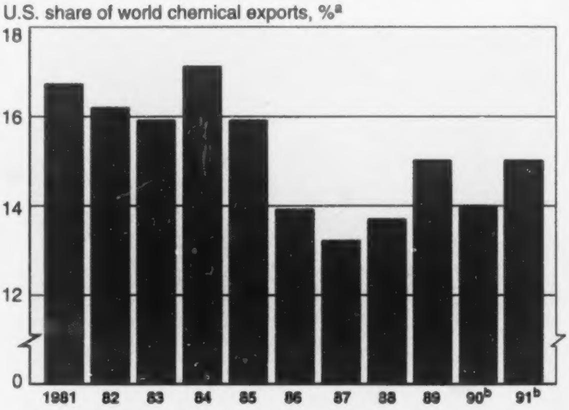
Note: Data for 1990, 1989, and 1988 have been revised according to SITC (Standard International Tariff Classification) revision 3. Earlier data have not been revised. **Source:** Department of Commerce

U.S. chemical trade balance holds strong . . .



a Running 12-month totals. **Source:** Department of Commerce

. . . as export market share increases



a U.S. chemical exports as a percentage of total world chemical exports less U.S. chemical imports. b C&EN estimates.

U.S. CHEMICAL TRADE: Exports to developing areas fuel overall growth

	1991		1990		1989		1988		% annual change, 1990–91	
$ Millions	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
European Community	$11,250	$10,418	$10,509	$ 9,728	$ 9,758	$ 9,158	$ 8,318	$ 9,066	7%	7%
Rest of Asia	7,172	1,445	6,566	1,267	6,624	985	5,712	844	9	14
Latin America	6,590	1,333	5,773	1,287	5,419	1,671	5,083	1,354	14	4
Canada	6,555	4,352	6,050	4,305	4,210	3,934	3,751	3,841	8	1
Japan	5,047	2,706	4,582	2,391	4,664	2,373	3,982	2,399	10	13
Communist Asia	1,671	392	1,054	337	1,136	273	1,309	230	59	16
Australia	1,357	421	1,247	344	1,364	291	1,066	329	9	22
Africa	715	95	628	90	702	61	594	106	14	6
Middle East	673	372	629	355	543	371	542	305	7	5
Eastern Europe	387	263	460	242	409	208	336	219	−16	9
Other	1,550	2,372	1,485	2,122	1,656	1,427	1,216	1,633	4	12
TOTAL	**$42,967**	**$24,169**	**$38,983**	**$22,468**	**$36,485**	**$20,752**	**$31,909**	**$20,326**	10%	8%

Source: Department of Commerce

WORLD CHEMICAL TRADE: Growth slows, despite gains by U.S. and Japan

	1991		1990		1989		1988		% annual change, 1990–91	
$ Millions	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
EC, 12 countries	$166,426	$143,914	$165,219	$141,643	$141,930	$119,022	$139,894	$112,497	1%	2%
Germany[a]	51,010	32,729	50,597	30,854	44,187	25,387	43,848	24,274	1	6
France	28,800	24,527	28,339	24,965	23,941	20,721	23,634	19,619	2	−2
U.K.	24,488	19,370	23,594	19,317	20,189	17,091	20,187	16,583	4	0
Netherlands	21,080	13,068	22,478	13,254	19,494	11,539	19,617	10,828	−6	−1
Belgium-Luxembourg	16,648	13,877	16,447	13,701	13,889	11,514	13,043	10,672	1	1
Italy	11,354	20,109	11,152	20,260	9,944	17,167	10,170	16,081	2	−1
U.S.	42,967	24,169	38,983	22,468	36,485	20,752	31,909	20,326	10	8
Japan	17,475	17,412	15,872	16,045	14,776	15,948	13,964	14,830	10	9
Switzerland	12,882	7,195	13,776	8,035	11,008	6,679	11,137	6,731	−7	−11
Canada	6,465	7,859	6,600	7,753	6,098	7,192	6,230	6,577	−2	1
WORLD	**$310,500[b]**	**$310,500[b]**	**$ 301,500[b]**	**$301,500[b]**	**$264,416**	**$264,416**	**$253,503**	**$253,503**	3%	3%

[a] Data prior to 1990 are for West Germany only. [b] C&EN estimates. **Sources:** United Nations, Organization for Economic Cooperation & Development, European Community, individual government agencies

U.S. TRADE, BY PRODUCTS: Exports of plastics and perfumes were big gainers last year

	1991		1990		1989		1988		% annual change, 1990–91	
$ Millions	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
Organic chemicals	$10,928	$ 8,157	$10,400	$7,392	$10,609	$ 7,042	$ 9,704	$ 7,250	5%	10%
Plastics in primary form	7,537	1,930	6,428	1,974	5,727	1,687	5,503	1,373	17	−2
Medicinals and pharmaceuticals	4,606	3,053	4,103	2,500	3,660	2,086	3,262	1,849	12	22
Inorganics	4,102	3,299	3,816	3,234	4,319	3,231	4,289	3,147	8	2
Fertilizers, manufactured	2,980	919	2,574	955	2,821	999	1,199	991	16	−4
Plastics in nonprimary form	2,786	1,855	2,633	1,774	2,202	1,629	2,001	1,574	6	5
Essential oils and perfume materials	2,361	1,417	1,963	1,323	1,469	1,165	1,126	1,175	20	7
Dyeing, tanning, and coloring materials	1,648	1,416	1,588	1,288	1,097	1,133	1,100	1,302	4	10
Other	6,020	2,123	5,478	2,028	4,583	1,780	3,725	1,665	10	5
TOTAL	**$42,967**	**$24,169**	**$38,983**	**$22,468**	**$36,485**	**$20,752**	**$31,909**	**$20,326**	10%	8%

Source: Department of Commerce

6 FOREIGN CHEMICAL INDUSTRIES - **WESTERN EUROPE**

Sluggish year for West European chemicals

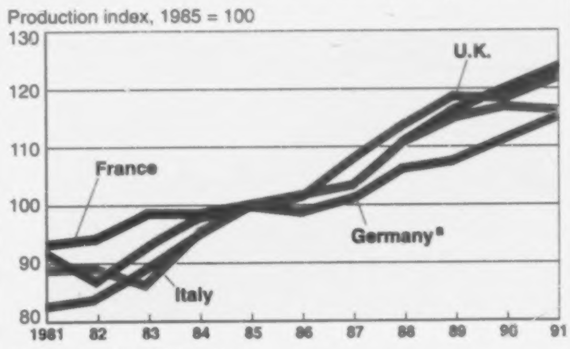
The chemical industry in Western Europe may have outpaced its counterpart in the U.S. in 1991, but just barely. Combined sales for the chemical producers of the 15 countries of the region edged up 2% last year, based on local currency sales figures. Chemical production increased modestly, too, for several of the key chemical-producing countries of the region, such as Germany, France, and the U.K. However, as in the U.S., profits were generally down for the second year in a row for chemical makers, and overall chemical employment in the 15 countries dropped 1%.

The biggest chemical-producing countries were generally the only ones to post gains last year. Chemical sales for Germany, France, and the U.K., which together account for just over half of Western Europe's chemical business, grew by $6.5 billion in 1991, a 3% increase, to reach $217 billion. Chemical sales from the other 12 nations, though they account for 47% of the region's chemical sales, rose only $200 million last year, to $194.4 billion.

And even production of many big-volume chemicals declined a bit. In Germany, for example, production of sulfuric acid fell 7%, chlorine fell 5%, and sodium hydroxide fell 4%. Among organic chemicals, propylene production rose 1% for the year, and ethylene output was unchanged. (Data for Germany here and in the accompanying tables and graphs include only the states of the former West Germany. Although the German government is working to integrate statistics from its eastern and western regions, data from the former East German states remain too sketchy to include in this report.)

The composition of the West European chemical industry, as far as major companies go, remained the same in 1991, although Germany's Hoechst nosed out BASF as the largest in terms of sales. Both income and profit margins throughout the industry continued to suffer, primarily because of soft prices. At Hoechst, for example, earnings were down 20% from 1990 levels, despite a 5% gain in sales. In fact, almost the only companies posting profit gains last year were those with extensive drug-making operations, such as Switzerland's Ciba-Geigy, Sandoz, and Roche Group.

U.K. chemical output recovers, Italy's stalls



a Includes only former West Germany.
Source: European Chemical Industry Council (CEFIC)

CHEMICAL INDUSTRY TRENDS: Sales growth slows as some prices fall

$ Billions (U.S.)	1991	1990	1989	1988	1987
GERMANY[a]					
Sales	$ 99.9	$ 98.1	$ 96.5	$ 90.9	$ 84.6
Exports	50.1	50.2	51.8	48.2	43.6
Imports	34.6	32.4	30.9	27.1	24.5
Capital spending	7.8	7.5	6.9	6.4	5.7
Production index[b]	114.8	112.4	109.4	106.5	101.1
Price index[b]	93.2	93.8	95.2	92.4	91.1
Employees (thousands)	594	592	582	575	572
FRANCE[c]					
Sales	$ 66.1	$ 63.9	$ 61.3	$ 56.5	$ 50.5
Exports	27.0	25.8	25.8	23.1	20.2
Imports	22.8	22.7	21.9	19.2	16.4
Capital spending	4.1	4.1	3.5	3.1	2.7
Production index[b]	123.7	120.3	118.2	111.4	104.1
Price index[b]	103.2	103.2	103.2	98.8	96.3
Employees (thousands)	265	263	264	257	268
U.K.[c]					
Sales	$ 51.0	$ 48.5	$ 48.3	$ 43.8	$ 39.8
Exports	24.7	23.6	22.1	20.1	18.7
Imports	19.5	19.2	18.5	16.5	14.8
Capital spending	3.3	3.6	3.3	3.1	2.5
Production index[b]	121.9	118.3	119.3	113.9	109.0
Price index[b]	126.5	121.7	116.4	111.5	105.8
Employees (thousands)	303	324	323	320	336

$ Billions (U.S.)	1991	1990	1989	1988	1987
ITALY					
Sales	$ 50.3	$ 50.2	$ 48.9	$ 46.0	$ 39.2
Exports	12.5	12.5	12.7	11.4	9.7
Imports	21.2	20.9	20.3	17.9	15.4
Capital spending	3.0	2.9	2.7	2.2	1.9
Production index[b]	115.9	117.1	115.0	112.5	103.6
Price index[b]	120.4	117.5	110.7	107.5	100.4
Employees (thousands)	217	217	220	223	225
SPAIN[c,d]					
Sales	$ 38.4	$ 39.0	$ 37.0	$ 34.1	$ 30.7
Exports	6.3	6.1	5.9	5.5	5.0
Imports	11.5	10.5	9.8	8.5	7.5
Capital spending	1.0	1.2	1.0	0.8	0.6
Production index[b]	130.9	132.5	128.6	122.5	112.4
Price index[b]	111.8	112.1	108.3	104.6	102.5
Employees (thousands)	240	240	240	239	239
BELGIUM[c,d,e]					
Sales	$ 27.9	$ 27.4	$ 26.9	$ 24.4	$ 21.6
Exports	20.9	20.2	19.9	17.6	16.0
Imports	17.6	17.0	16.5	14.5	11.7
Capital spending	2.7	3.1	2.1	1.7	1.1
Production index[b]	129.9	128.4	124.9	120.2	110.6
Price index[b]	98.1	98.8	102.1	96.5	94.0
Employees (thousands)	99	97	95	92	91
NETHERLANDS					
Sales	$ 24.3	$ 24.6	$ 25.4	$ 23.7	$ 21.2
Exports	23.1	23.5	25.1	23.1	20.6
Imports	13.9	13.8	17.2	13.3	12.5
Capital spending	2.3	2.0	2.3	1.6	1.6
Production index[b]	120.0	120.0	118.0	112.0	104.0
Price index[b]	87.0	89.0	92.0	88.0	87.0
Employees (thousands)	92	93	93	92	91
SWITZERLAND					
Sales	$ 15.6	$ 15.0	$ 14.5	$ 13.0	$ 12.0
Exports	13.3	12.9	12.5	11.0	10.2
Imports	7.4	7.4	7.6	6.5	5.8
Production index[b]	120.6	119.6	119.0	109.4	105.3
Price index[b]	97.9	97.9	93.0	91.9	90.8
Employees (thousands)	72	73	72	70	69
SWEDEN					
Sales	$ 7.8	$ 8.2	$ 7.8	$ 7.6	$ 6.6
Exports	4.7	4.2	3.9	3.6	3.1
Imports	5.1	5.1	5.0	4.7	4.1
Capital spending	0.7	0.7	0.5	0.5	0.5
Production index[b]	109.0	118.5	115.0	119.6	106.3
Price index[b]	122.0	118.0	116.0	110.5	103.2
Employees (thousands)	40	42	42	43	45

$ Billions (U.S.)	1991	1990	1989	1988	1987
AUSTRIA[d]					
Sales	$ 7.7	$ 7.8	$ 7.9	$ 7.4	$ 6.8
Exports	3.6	3.4	3.4	3.2	2.7
Imports	4.9	4.8	4.4	4.0	3.8
Capital spending	0.8	0.9	0.7	0.6	0.6
Production index[b]	105.2	105.4	103.8	100.0	87.3
Employees (thousands)	54	57	57	56	55
PORTUGAL					
Sales	na	$ 5.4	$ 5.0	$ 4.8	$ 1.7
Exports	$ 0.8	0.6	1.0	0.8	0.6
Imports	2.1	1.9	2.3	1.9	1.8
Production index[b]	na	na	172.2	163.2	151.9
Employees (thousands)	na	na	64	51	51
IRELAND[c]					
Sales	$ 5.1	$ 4.6	$ 4.2	$ 3.3	$ 2.7
Exports	4.3	3.7	3.4	2.6	2.1
Imports	2.8	2.5	2.5	2.1	1.8
Production index[b]	181.5	149.0	144.8	124.1	108.1
Price index[b]	91.1	92.5	96.8	93.4	91.7
Employees (thousands)	15	14	13	12	12
DENMARK					
Sales	$ 4.4	$ 4.3	$ 4.4	$ 3.8	$ 4.0
Exports	3.4	3.2	3.6	2.8	2.6
Imports	3.6	3.6	4.0	3.3	3.0
Capital spending	na	0.3	0.4	0.3	0.3
Production index[b]	111.6	110.9	111.0	107.0	105.4
Price index	116.1	112.4	109.0	104.0	99.0
Employees (thousands)	27	27	27	26	26
FINLAND					
Sales	na	$ 4.2	$ 4.2	$ 3.6	$ 3.9
Exports	$ 1.6	1.6	1.6	0.6	0.7
Imports	2.5	2.7	2.8	1.0	1.2
Capital spending	na	0.5	0.4	0.4	0.5
Production index[b]	108.5	116.8	120.2	113.4	92.1
Price index[b]	110.9	109.1	107.8	102.4	95.0
Employees (thousands)	na	20	20	20	24
NORWAY					
Sales	$ 3.3	$ 3.5	$ 3.3	$ 3.1	$ 3.0
Exports	2.1	2.1	2.0	1.9	1.7
Imports	2.3	2.1	2.0	1.9	1.7
Capital spending	na	0.2	0.2	0.2	0.2
Production index[b]	111.5	117.0	108.6	103.0	103.0
Price index[b]	122.5	120.3	122.0	114.0	106.0
Employees (thousands)	14	14	14	14	15

Note: Monetary statistics for all years are converted from local currency to U.S. dollars on the basis of 1991 conversion rates as follows: $1.00 = 11.68 Austrian schillings, 34.25 Belgian francs, 6.40 Danish crowns, 4.04 Finnish marks, 5.64 French francs, 1.66 German marks, 0.619 Irish pounds, 1241 Italian lire, 1.87 Netherlands guilders, 6.48 Norwegian crowns, 144.5 Portuguese escudos, 103.9 Spanish pesetas, 6.05 Swedish crowns, 1.43 Swiss francs, and 0.565 British pounds. **a** Includes former West Germany only. **b** 1985 = 100. **c** Excludes fibers. **d** Includes rubber and plastics processing. **e** Includes Luxembourg for exports and imports. **na** = not available. **Sources:** National agencies, European Chemical Industry Council (CEFIC)

MAN-MADE FIBERS: Cellulosics output down, uneven results for other fibers

Millions of lb	1991		1990		1989		1988		1987		% change, 1990–91	
	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics
Germany	1767	385	1848	396	1841	394	1817	376	1806	356	−4%	−3%
Italy	1522	79	1450	79	1412	77	1452	70	1441	64	5	0
Benelux countries	605	114	568	117	521	119	385	119	399	109	7	−3
Spain	557	66	585	79	592	88	590	81	591	78	−5	−17
Turkey	na	na	535	20	645	20	592	20	572	18	na	na
U.K.	513	218	506	266	493	255	515	238	513	208	1	−18
France	260	0	343	0	392	4	392	33	382	50	−24	—
Switzerland	224	0	260	0	264	0	255	0	227	0	−14	—
Ireland	205	0	205	0	207	0	176	0	172	0	0	—
Portugal	141	0	141	1	141	2	128	2	139	2	0	—
Austria	84	262	84	297	77	301	70	290	68	264	0	−12
Finland	13	103	11	141	7	143	7	132	4	118	18	−27

na = not available. **Source:** Comité International de la Rayonne et des Fibres Synthétiques

PRODUCTION: Generally down in Germany and Italy, mixed in France and the U.K.

Millions of lb	1991	1990	1989	1988	% change 1990–91
FRANCE					
Sulfuric acid	7970	8306	9141	8846	−4%
Hydrochloric acid	1441	1488	1525	1507	−3
Chlorine	2790	2956	3185	3121	−6
Sodium hydroxide	2933	3143	3370	3258	−7
Carbon black	494	556	595	531	−11
Ammonia	na	3257	3249	4031	—
Benzene	1542	1434	1474	1544	8
Toluene	na	74	74	104	—
Xylenes	na	na	372	493	—
Ethylene	5320	4948	5562	5361	8
Propylene	3546	3157	3480	3298	12
Butadiene	623	619	724	737	1
Formaldehyde	95	220	221	193	−57
Polyethylene	2643	2461	2549	2620	7
Polypropylene	1790	1715	1544	1278	4
Polystyrene	1164	1193	1192	1177	−2
Polyvinyl chloride	2310	2265	2350	2237	2
Synthetic rubber	1036	1151	1300	1251	−10
Nitrogen fertilizers	4026	4655	4373	4343	−14
Phosphate fertilizers[a]	554	626	707	700	−12
GERMANY[b,c]					
Sulfuric acid	6831	7370	7165	7186	−7
Hydrochloric acid	1854	1982	2107	2160	−7
Nitric acid	2957	3936	4807	5098	−25
Chlorine	6795	7175	7574	7701	−5
Sodium hydroxide	6829	7129	7370	7602	−4
Sodium carbonate	3008	3166	3175	3089	−5
Sodium sulfate	300	368	379	385	−19
Carbon black	823	870	884	836	−5
Ammonia	3500	3686	4573	4816	−5
Benzene	3419	3287	3443	3536	4
Toluene	1330	1184	919	1013	12
Xylenes	1155	1276	1345	1296	−10
Aniline	na	na	376	386	—
Ethylene	6790	6773	6588	6889	0
Propylene	4053	4028	3819	3396	1
Butadiene	1494	1714	1579	1677	−13
Ethylene oxide	1282	1386	1482	1381	−8
Ethylene glycol	na	464	543	521	—
Propylene oxide	1328	1302	1299	1209	2
Propylene glycol	387	394	399	427	−2
n-Butanol	766	781	741	685	−2
Acetaldehyde	na	771	709	789	—
Acetic acid	734	713	701	754	3
Ethanol	245	234	224	228	5
Methanol	1660	1656	1535	na	0%
Formaldehyde	1442	1500	1534	1505	−4
Phthalic anhydride	452	507	506	612	−11
Polyethylene	3011	3254	3064	3235	−8
Polyvinyl chloride	2560	2913	2948	3105	−12
Polypropylene	1165	1121	na	na	−4
Synthetic rubber	1126	1154	1119	1101	−4
Nitrogen fertilizers[d]	1363	1816	1500	na	−25
Phosphate fertilizers[a]	150	165	197	na	−9
ITALY[c]					
Sulfuric acid	6246	7190	7084	9478	−13
Nitric acid	2166	2286	2443	2625	−6
Hydrochloric acid	1240	1630	1400	2218	−24
Phosphoric acid	385	497	618	785	−23
Chlorine	1822	2300	2349	2385	−21
Sodium hydroxide	2286	2427	2598	2618	−6
Sodium perborate	266	271	276	242	−2
Carbon black	405	405	446	442	0
Ammonia	2883	3207	3882	3846	−10
Benzene	1151	1351	1447	1368	−15
Toluene	363	423	338	480	−14
Xylenes	750	841	1023	986	−11
Formaldehyde	220	251	258	277	−12
Acetic acid	21	21	99	145	0
Polyethylene	2067	2053	1937	1822	−2
Polystyrene	840	778	590	627	8
Polyvinyl chloride	1360	1362	1801	1740	0
Nitrogen fertilizers[d]	4660	5261	6210	7176	−11
U.K.[c]					
Sulfuric acid[e]	3086	2847	2543	na	8
Hydrochloric acid[e]	345	358	367	388	−4
Chlorine	1952	2073	na	na	−6
Sodium hydroxide[e]	473	346	na	na	37
Benzene	1334	1544	2260	2072	−14
Ethylene	3881	3296	4356	4464	18
Propylene	1857	1653	1757	2985	12
Butadiene	326	436	498	527	−25
Acetone	274	283	287	280	−3
Formaldehyde	102	176	176	246	9
Polyethylene	828	740	989	1015	12
Polypropylene	694	653	657	692	6
Polyvinyl chloride	710	768	736	740	−8
Synthetic rubber	602	657	687	688	−8

a As P_2O_5. **b** Data are for the former West Germany only. **c** Data for 1991 are C&EN estimates based on nine months' reporting. **d** As N. **e** Manufacturers' sales. **na** = not available. **Sources:** British Plastics Federation, British Rubber Institute, government agencies for each country

COMPANY RESULTS: Profits rose for drugmakers, fell for most other firms

$ Millions	Net sales	Net income	Profit margin[a]	Capital spending	R&D spending	Employees (thousands)
Hoechst (Germany)						
1991	$28,425.0	$ 817.5	2.9%	$2160.2	$1728.3	179.3
1990	27,025.3	1021.7	3.8	2047.5	1618.6	172.9
1989	27,649.3	1283.1	4.6	1925.8	1578.9	169.3
1988	24,677.1	1213.9	4.9	1674.6	1455.4	164.5
BASF (Germany)						
1991	$28,088.0	$ 625.9	2.2%	$2891.6	$1242.8	129.4
1990	28,086.1	666.8	2.4	2685.6	1242.8	134.6
1989	28,684.9	1214.0	4.2	2383.1	1246.4	137.0
1988	26,426.5	862.8	3.2	2105.4	1177.2	134.8
Bayer (Germany)						
1991	$25,542.8	$1116.3	4.4%	$1851.8	$1811.4	164.2
1990	25,086.2	1146.4	4.6	2221.0	1649.4	171.0
1989	26,083.7	1274.6	4.9	2076.5	1623.5	170.2
1988	24,378.3	1156.0	4.7	1894.5	1481.9	165.7
ICI (U.K.)						
1991	$22,102.7	$ 959.3	4.3%	$1569.9	$1224.8	128.6
1990	22,842.5	1023.0[b]	4.8	1792.9	1201.8	132.1
1989	23,311.5	1646.0[c]	7.1	1911.5	1131.0	133.8
1988	20.706.2	1559.3[d]	7.5	1435.4	1000.0	130.4
Rhône-Poulenc (France)						
1991	$14,861.2	$ 355.3	2.4%	$1371.5	$1017.0	87.0
1990	13,973.5	344.3	2.5	1329.7	939.7	91.6
1989	12,955.4	725.5	5.6	1244.0	749.9	85.6
1988	11,584.1	612.9	5.3	1046.3	677.8	79.7
Ciba-Geigy (Switzerland)						
1991	$14,739.2	$ 895.1	6.1%	$1368.5	$1528.0	91.7
1990	13,778.3	760.1	5.2	1439.2	1434.3	94.1
1989	14,411.2	753.8	7.5	1389.5	1451.0	92.6
1988	12,340.6	659.4	7.5	1130.1	1256.6	88.8
EniChem (Italy)						
1991	$10,817.1	$ (581.8)[e]	—	na	na	na
1990	12,135.3	(54.7)[e]	—	$1477.9	$ 259.5	49.0
1989	12,366.7	577.0	4.7%	1598.1	na	52.7
1988[f]	11,814.7	708.7	6.0	965.4	na	54.7
Norsk Hydro (Norway)						
1991	$ 9,478.9	$ (76.9)[e]	—	$1401.2	$ 136.0	35.0
1990	9,409.3	447.7	4.8%	1260.8	111.6	33.0
1989	10,236.0	414.7	4.1	1762.2	100.2	32.8
1988	9,263.6	530.0	5.7	1363.6	114.2	39.5
Sandoz (Switzerland)						
1991	$ 9,401.4	$ 779.0	8.3%	$ 886.7	$ 928.7	53.4
1990	8,648.3	676.2	7.8	888.1	844.8	52.6
1989	8,739.2	669.9	7.7	752.4	772.0	50.7
1988	7,098.6	532.2	7.5	585.3	637.8	48.0
Akzo (Netherlands)						
1991	$ 9,011.2	$ 363.1[g]	4.0%	$ 538.5	$ 479.1	65.2
1990	9,222.5	382.9[h]	4.2	603.7	476.5	69.8
1989	10,019.3	517.6	5.1	693.6	483.4	70.9
1988	8,866.8	472.2	5.3	679.1	433.2	71.1
Degussa (Germany)						
1991	$8042.2	$ 59.6	0.7%	$ 471.7	$ 291.6	34.5
1990[i]	8388.6	88.5	1.1	410.2	275.9	35.0
1989[i]	8648.8	105.4	1.2	319.8	254.3	33.7
1988[i]	8195.8	88.0	1.1	270.7	226.0	32.4
Solvay (Belgium)						
1991	$7439.4	$ 309.8[j]	4.2%	$ 989.8	$ 375.6	45.6
1990	7452.3	519.7[k]	7.0	1065.7	375.1	45.7
1989	7497.8	603.5[l]	8.0	899.2	350.4	45.1
1988	7400.5	441.1[m]	6.0	691.9	315.0	44.3
Roche Group (Switzerland)						
1991	$8007.7	$1036.4	12.9%	$ 796.5	$1207.7	55.1
1990	6762.2	662.3	9.8	634.3	1009.8	52.7
1989	6862.9	595.8	8.7	635.0	992.3	50.2
1988	6076.9[n]	449.0[n]	7.4	445.9	846.2	47.2[n]
DSM (Netherlands)						
1991	$4998.4	$ 275.9	5.5%	$ 939.0	$ 227.3	25.2
1990	5435.3	459.4[o]	8.0	700.5	227.3	24.9
1989	5760.4	738.0[p]	9.6	930.5	213.9	30.0
1988	5412.3	332.6[q]	7.8	712.3	192.5	28.6
Air Liquide (France)						
1991	$5641.6	$ 391.8	6.9%	$ 773.8	$ 134.2	28.0
1990	5126.7	349.5[r]	6.8	703.1	130.0	na
1989	5009.1	320.2[s]	6.4	533.5	157.8	27.0
1988	4543.8	280.9	6.2	406.7	128.2	na
BOC International (U.K.)						
1991[i]	$4810.6	$ 342.5	7.1%	$ 658.6	$ 112.7	39.7
1990[i]	2643.9	241.9	9.2	308.0	62.2	40.0
1989[i]	2309.1	229.3	9.9	344.8	54.6	38.4
1988[i]	2119.5	205.2[t]	9.7	294.2	46.8	38.8
Nobel Industries (Sweden)						
1991	$4085.5	$ 76.0[u]	1.9%	$ 322.5	na	22.9
1990	4451.7	169.1[v]	3.9	401.5	na	26.7
1989	3650.9	180.3[w]	6.2	239.5	na	22.2
1988	3524.3	100.5	4.4	178.7	na	22.1
Courtaulds (U.K.)						
1991[x]	$3438.2	$ 268.3	7.8%	$ 212.4	$ 70.8	22.7
1990[x]	3383.4	255.8[y]	7.6	na	70.8	24.0
1989[x]	3369.9	223.0[z]	6.6	na	72.4	24.0
1988[x]	2916.8	196.5[aa]	6.7	na	60.0	20.8
Schering Group (Germany)						
1991	$3831.3	$ 165.1[bb]	4.3%	$ 294.0	$ 580.7	26.3
1990	3568.1	155.7[cc]	4.4	308.7	563.1	26.7
1989	3521.0	135.5	3.9	276.4	442.9	25.3
1988	3176.0	94.6	3.0	247.6	379.6	24.7
Kemira (Finland)						
1991	$2685.1	$(141.3)[dd,e]	—	$ 292.1	na	14.3
1990	2817.3	41.3[ee]	1.5%	281.2	na	15.3
1989	2729.7	45.0	1.6	397.3	na	16.0
1988	2284.2	129.2	5.7	357.7	na	14.9

Note: All corporate consolidated sales exclude sales of companies owned less than 50%. **a** Net income as a percentage of sales. **b** Excludes nonrecurring gain of $163 million. **c** Excludes nonrecurring gain of $225 million. **d** Excludes nonrecurring loss of $78 million. **e** Net loss. **f** Pro forma. **g** Excludes nonrecurring loss of $59 million. **h** Excludes nonrecurring loss of $34 million. **i** Fiscal year ends Sept. 30. **j** Excludes nonrecurring gain of $53 million. **k** Excludes nonrecurring loss of $55 million. **l** Excludes nonrecurring loss of $113 million. **m** Excludes nonrecurring loss of $147 million. **n** Restated to reflect sale of operations. **o** Excludes nonrecurring gain of $25 million. **p** Excludes nonrecurring gain of $184 million. **q** Excludes nonrecurring loss of $93 million. **r** Excludes nonrecurring gain of $45 million. **s** Excludes nonrecurring gain of $57 million. **t** Excludes nonrecurring loss of $25 million. **u** Excludes nonrecurring net loss of $916 million. **v** Excludes nonrecurring net gain of $23 million. **w** Excludes nonrecurring gain of $32 million. **x** Fiscal year ends March 31. **y** Excludes nonrecurring loss of $122 million. **z** Excludes nonrecurring loss of $74 million. **aa** Excludes nonrecurring gain of $218 million. **bb** Excludes nonrecurring loss of $48 million. **cc** Excludes nonrecurring loss of $55 million. **dd** Excludes nonrecurring loss of $23 million. **ee** Excludes nonrecurring loss of $45 million. **na** = not available.

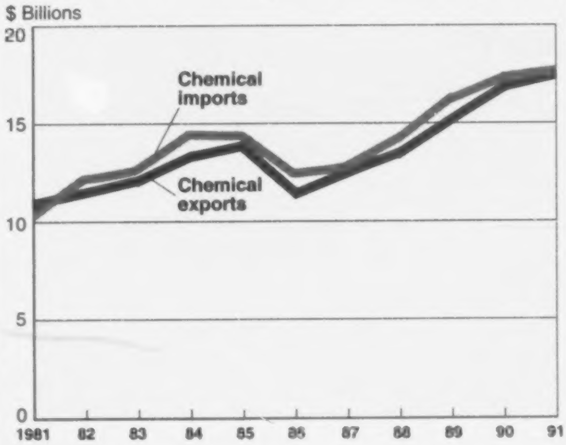
6 FOREIGN CHEMICAL INDUSTRIES - **JAPAN**

Japanese chemical companies sailed into the unfamiliar waters of an economic downturn last year. They did not enjoy the trip.

Although sales were down only slightly, profits and earnings were significantly lower than a year earlier. For 12 top Japanese chemical companies, earnings fell by 38% between the first and second halves of fiscal 1991, which ended this March. By the end of the period, profit margins averaged a mere 2% of sales, down from 4% or more in 1989 and early 1990.

Production of most chemicals, however, rose last year, helped by slightly higher Japanese chemical exports. Chemical employment also continued to grow, as the top 12 companies boosted total employees 3% to nearly 94,000.

Japan's chemical imports balance exports



Note: Monetary statistics for all years are converted from yen to U.S. dollars on the basis of the average 1991 exchange rate of $1.00 = 134.48 yen. **Source:** Ministry of International Trade & Industry

INDUSTRY TRENDS: Most fields gain slightly

Production index, 1985 = 100	1991	1990	1989	1988	% change 1990–91
All manufacturing	128.2	125.6	120.0	113.1	2%
All chemicals	137.3	134.4	128.7	120.4	2
Inorganic chemicals and pigments	115.7	114.3	114.4	108.4	1
Alkalies and chlorine	119.8	120.9	114.7	110.5	−1
Organic chemicals	137.4	131.7	128.1	115.9	4
Petrochemicals	140.4	136.7	129.1	118.1	3
Aromatics	147.4	137.3	133.2	115.9	7
Cyclic intermediates and dyes	148.4	141.6	135.3	121.2	5
Plastics	141.3	139.6	130.7	120.6	1
Synthetic fibers	102.1	101.2	97.5	95.4	1
Synthetic rubber	118.2	123.1	116.7	112.2	−4
Fertilizer	83.3	85.2	86.6	88.5	−2
Textile chemicals	133.1	126.8	118.7	117.8	5
Medicinals and drugs	159.4	155.2	147.3	136.2	3

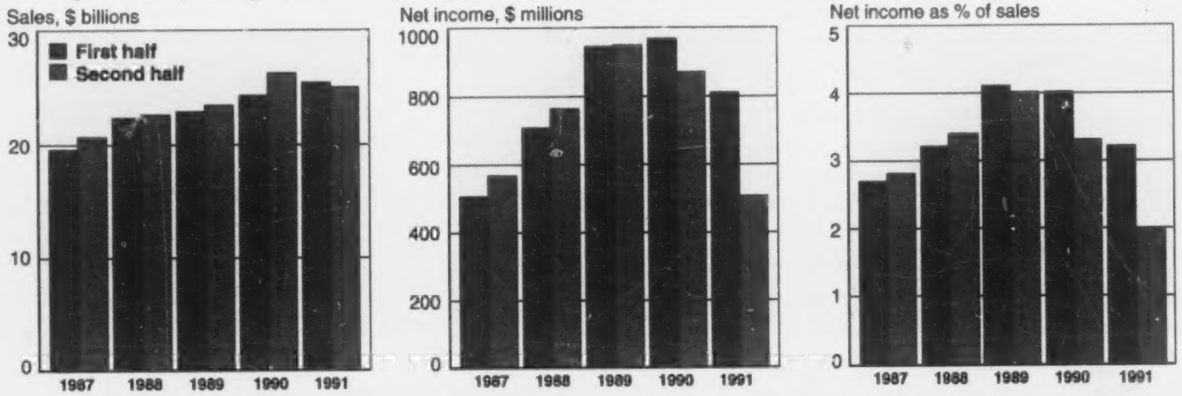
Source: Ministry of International Trade & Industry

PRODUCTION: Stays surprisingly strong

Thousands of metric tons, unless otherwise indicated	1991	1990	1989	1988	% change 1990–91
INORGANIC CHEMICALS					
Ammonia	1855	1831	1831	1817	1%
Ammonium chloride	239	246	274	299	−3
Ammonium sulfate	1781	1803	1717	1834	−1
Calcium carbide	303	294	344	342	3
Calcium superphosphate	420	472	454	476	−11
Carbon black	793	783	779	720	1
Chlorine, liquid	1027	1042	1009	979	−1
Hydrochloric acid	702	637	571	565	10
Nitrogen, millions of cu m	8767	8299	7856	6940	5
Oxygen, millions of cu m	9000	8787	8384	7707	2
Sodium carbonate	1104	1135	1105	1083	−3
Sodium hydroxide	3905	3917	3674	3508	0
Sodium silicate	787	788	756	721	0
Sulfuric acid	7057	6887	6885	6766	3
Titanium dioxide	279	280	275	258	0
ORGANIC CHEMICALS					
Acetaldehyde	384	384	356	333	0
Acetic acid	458	462	432	402	−1
Acetone	369	334	337	289	11
Acrylonitrile	604	593	611	600	2
Benzene[a]	3050	2768	2672	2374	10
Butadiene	847	827	827	780	2
Butanol	334	300	291	276	11
Caprolactam	531	509	469	493	4
Cyclohexane	577	629	656	561	−8
Dioctyl phthalate	305	295	293	273	3
Ethylene	6142	5810	5602	5057	6
Ethylene dichloride	2642	2660	2464	2301	−1
Ethylene glycol	609	501	548	349	22
Ethylene oxide	760	674	681	510	13
Methanol	77	84	82	141	−8
Octanol	295	283	285	273	4
Phenol	495	403	423	358	23
Phthalic anhydride[a]	162	161	160	171	1
Propylene	4337	4215	4036	3682	3
Propylene glycol	301	298	285	265	1
Styrene	2227	2161	1990	1757	3
Terephthalic acid	1434	1338	1200	1150	7
Toluene	1119	1078	1075	1019	4
Toluene diisocyanate	136	116	104	96	17
Urea	730	776	810	790	−6
Xylene	2918	2652	2488	1988	10
PLASTICS					
Phenolic resins	383	385	375	356	−1
Polyethylene	2982	2888	2712	2380	3
Polypropylene	1963	1942	1719	1559	1
Polystyrene	2121	2097	1997	1891	1
Polyvinyl chloride	2055	2049	1972	1838	0
SYNTHETIC RUBBER	1368	1426	1352	1299	−4

[a] Petroleum-based product only. **Source:** Ministry of International Trade & Industry

Sales, income, and profitability all declining for Japanese chemical companies



Note: Based on results of 12 leading Japanese chemical companies: Asahi Chemical, Dainippon Ink & Chemicals, Hitachi Chemical, Mitsubishi Kasei, Mitsubishi Petrochemical, Mitsui Toatsu Chemicals, Sekisui Chemical, Showa Denko, Sumitomo Chemical, Takeda Chemical Industries, Teijin, and Toray Industries. The fiscal year for most, but not all, of these companies ends March 31. **Sources:** Toyo Keizai Shinposha, Nihon Keizai Shimbon America

COMPANY RESULTS: Profits take a beating at every major chemical company

$ Millions	Net sales	Net income	Profit margin[a]	Total assets	Employees (thousands)
Asahi Chemical Industry[b]					
1991	$7249	$218.2	3.0%	$7726	15.5
1990	7177	287.7	4.0	7424	15.3
1989	6539	247.1	3.8	6632	15.1
1988	6081	209.0	3.4	6106	15.4
Mitsubishi Kasei[b]					
1991	$5408	$ 39.7	0.7%	$7778	9.1
1990	5730	137.9	2.4	7377	9.1
1989	5442	134.1	2.5	6789	8.9
1988	5841	119.0	2.0	6642	8.8
Sumitomo Chemical[c]					
1991	$5214	$113.3	2.2%	$6676	7.9
1990	5330	123.3	2.3	6016	7.8
1989	4474	149.4	3.3	5875	7.7
1988	4135	110.9	2.7	5530	7.7
Sekisui Chemical[b]					
1991	$4833	$158.1	3.3%	$4693	5.8
1990	4589	194.3	4.3	4563	5.6
1989	4120	175.9	4.3	3501	5.4
1988	3749	134.8	3.6	2780	5.2
Toray Industries[b]					
1991	$4455	$202.0	4.5%	$6179	10.4
1990	4353	215.5	5.0	5587	10.3
1989	4083	233.5	5.7	5498	9.6
1988	4113	128.3	3.1	5266	10.0
Showa Denko[c]					
1991	$4289	$ 1.4	0%	$6284	5.4
1990	4236	84.2	2.0	5857	5.3
1989	3907	99.5	2.5	4568	5.1
1988	3505	67.9	1.9	4095	5.1
Takeda Chemical Industries[b]					
1991	$4171	$241.4	5.8%	$5525	11.1
1990	4096	275.9	6.7	5405	11.0
1989	4371	278.6	6.4	5414	10.9
1988	4350	256.6	5.9	5104	10.8
Dainippon Ink & Chemicals[b]					
1991	$3848	$ 59.0	1.5%	$4810	7.0
1990	3757	61.7	1.6	4363	7.2
1989	3493	64.0	1.8	4100	6.9
1988	3277	59.2	1.8	3880	6.7
Mitsui Toatsu Chemicals[b]					
1991	$3140	$ 52.9	1.7%	$4739	5.6
1990	3247	92.6	2.9	4631	5.5
1989	3074	89.5	2.9	4064	5.4
1988	2935	79.6	2.7	3750	5.4
Mitsubishi Petrochemical[b]					
1991	$3025	$114.9	3.8%	$4665	3.4
1990	3230	192.3	6.0	4544	3.3
1989	2866	233.6	8.2	4487	3.0
1988	2531	155.1	6.1	3327	2.9
Teijin[b]					
1991	$2522	$110.7	4.4%	$4349	6.8
1990	2422	151.0	6.2	4331	5.7
1989	2273	158.8	7.0	4116	5.7
1988	2322	130.0	5.6	3642	5.8
Hitachi Chemical[b]					
1991	$2314	$ 7.9	0.3%	$1630	5.8
1990	2340	30.1	1.3	1501	5.3
1989	2105	32.5	1.5	1312	5.1
1988	2056	26.9	1.3	1201	5.0

Note: Monetary statistics for all years are converted from yen to U.S. dollars on the basis of the 1991 average exchange rate of $1.00 U.S. = 134.48 yen. **a** Net income as a percentage of sales. **b** Fiscal year ends March 31. **c** Fiscal year ends Dec 31. **Sources:** Toyo Keizai Shinposha, Nihon Keizai Shimbon America

6 FOREIGN CHEMICAL INDUSTRIES - **CANADA**

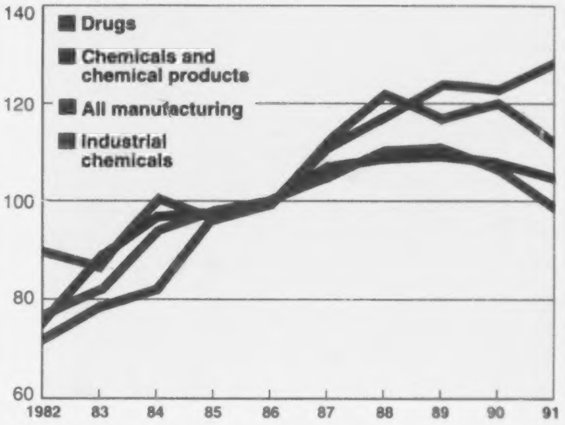
Last year was not a good one for the Canadian chemical industry. Although a few—very few—companies were able to boost sales, profits were down virtually across the board. A case in point: Novacor's net income plummeted from $325 million in 1990 to only $25 million last year.

There is no shortage of reasons: overcapacity for some of the important commodity chemicals; weak prices; and a recession, both in the Canadian domestic market and in the U.S., by far the major export market for Canadian chemical companies. Canadian chemical exports to the U.S. were down 3.9% last year and overall exports were 3.3% lower than in 1990.

As a result, production of most chemicals was lower, in some cases sharply lower. For industrial chemicals as a group, production fell 7% last year, even more than the 6% drop for all Canadian manufacturing. Drugmakers in general showed their resistance to recession; production for the group rose 5% in 1991. And a very few commodity chemicals also did well: High-density polyethylene production was up almost 26%, even though output of its low-density cousin was down about 5%.

Only drugs survive production downturn

Production index, 1986 = 100



Source: Statistics Canada

Note on currency conversion: Monetary statistics in this section have been converted from Canadian dollars to U.S. dollars on the basis of the average 1991 exchange rate of $1.00 U.S. equals $1.1458 Canadian.

COMPANY RESULTS: Profits nose-dive

$ Millions (U.S.)	Sales	Net income[a]	Profit margin[b]	Capital expenditures	Employees (thousands)
Celanese Canada					
1991	$ 392.6	$ 29.8	7.6%	$ 23.1	1.7
1990	318.2	36.0	11.3	21.0	1.8
1989	346.1	42.2	12.2	15.0	1.9
1988	355.4	42.7	12.0	21.4	2.1
Du Pont Canada					
1991	$1156.7	$ 49.0	4.2%	$124.0	4.2
1990	1231.8	54.5	4.4	157.4	4.3
1989	1236.6	75.5	6.1	96.8	4.1
1988	1202.7	102.9	8.6	87.6	4.0
Esso Chemical Canada[c]					
1991	$ 754.9	$ 1.7	0.2%	$ 22.7	1.4
1990	798.6	20.9	2.6	36.7	1.4
1989	837.8	69.8	8.3	43.6	1.5
1988	864.0	90.8	10.5	27.9	1.4
Novacor Chemicals					
1991	$1966.3	$ 25.3[d]	1.3%	$ 96.9	3.0
1990	2877.5	325.5[d]	11.3	188.5	3.3
1989	2937.7	446.0[d]	15.2	276.7	6.5
1988	1832.8	562.1[d]	30.7	126.5	6.5

[a] Excludes extraordinary gains and losses. [b] Net income as a percentage of sales. [c] Now the chemical division of Imperial Oil Ltd. [d] Includes operating income only.

PRODUCTION: Very few increases in any sector

Thousands of metric tons	1991	1990	1989	1988	% change 1990–91
INORGANIC CHEMICALS					
Ammonia	3669	3715	4054	4012	−1.2%
Ammonium nitrate	963	1031	1056	990	−6.6
Ammonium phosphate	na	803	952	986	—
Carbon black	157	178	190	181	−11.8
Chlorine	1402	1542	1592	1664	−9.1
Hydrochloric acid	193	187	180	180	3.2
Nitric acid	912	965	1027	919	−5.5
Phosphoric acid, 100% P_2O_5	348	402	470	475	−13.4
Sodium chlorate	695	659	593	503	5.5
Sodium hydroxide	1498	1650	1679	1720	−9.2
Sulfuric acid	2953	3311	3560	3805	10.8
Zinc oxide	na	31	41	62	—
ORGANIC CHEMICALS					
Benzene	712	762	670	695	−6.6
Butadiene	na	192	175	182	—
Butylene	169	176	151	148	−4.0
Ethylene	2425	2434	2317	2346	−0.4
Formaldehyde	114	106	112	123	7.5
Methanol	2223	1884	2015	2101	18.0
Propylene	717	765	719	672	−6.3
Toluene	364	425	397	417	−14.4
Urea	2397	2490	2402	2372	−3.7
Xylenes	391	514	432	399	−23.9
PLASTICS					
Polyesters, unsaturated	33	36	37	43	−8.3
Polyethylene, high density	458	364	303	311	25.8
Polyethylene, low density	1111	1167	1039	1105	−4.8
Polystyrene[a]	167	215	196	216	−22.3

[a] Includes acrylonitrile-butadiene-styrene resins. **na** = not available. **Source:** Statistics Canada

SHIPMENTS: Chemicals slipped, but not as badly as all manufacturing

$ Millions (U.S.)	1991	1990	1989	1988	1987	1986	% change 1990–91
All manufacturing	$241,396	$256,643	$259,180	$251,832	$234,366	$221,106	−6%
Chemicals and chemical products	18,885	19,489	19,206	19,129	17,341	16,267	−3
Industrial chemicals, inorganic	2,075	2,242	2,123	2,094	2,054	1,906	−7
Industrial chemicals, organic	4,070	4,511	4,719	5,230	4,243	3,797	−10
Plastics and synthetic resins	2,257	2,460	2,237	2,184	1,941	1,806	−8
Pharmaceuticals and medicinals	3,290	3,045	2,915	2,715	2,448	2,172	8
Adhesives	157	168	190	181	174	165	−6
Paint and varnish	1,363	1,412	1,342	1,310	1,224	1,085	−4
Soaps and cleansers	1,455	1,325	1,434	1,331	1,282	1,315	10
Toilet preparations	915	858	983	927	876	824	7
Printing ink	208	230	219	223	210	233	−10
Synthetic fibers	784	819	893	850	808	740	−4
Plastic products	4,661	4,977	4,885	4,727	4,255	3,822	−6

Source: Statistics Canada

CHEMICAL IMPORTS: Holding steady

$ Millions (U.S.)	1991	1990	1989	1988
Inorganic chemicals	$1136	$1142	$1220	$ 971
Organic chemicals	1739	1810	1696	1675
Fertilizers and fertilizer materials	190	192	161	212
Synthetic and reclaimed rubber	223	245	240	245
Plastic materials	1364	1327	1280	1174
Plastic film and sheet	460	442	441	421
Other plastic shapes and forms	402	427	438	458
Dyes, except dyeing intermediates	89	95	99	93
Pigments, lakes, and toners	127	116	123	124
Paints and related products	276	255	240	207
Other chemical products	1222	1169	1153	1017
TOTAL	**$7230**	**$7220**	**$7091**	**$6596**
Imports from U.S.	**$5540**	**$5433**	**$5228**	**$4651**
U.S. share	**77%**	**75%**	**74%**	**71%**

Source: Statistics Canada

CHEMICAL EXPORTS: Post unwelcome drop

$ Millions (U.S.)	1991	1990	1989	1988
Chemical elements	$ 154	$ 182	$ 176	$ 212
Other inorganic chemicals	1035	1065	1148	1236
Organic chemicals	1541	1773	1600	1690
Fertilizers and fertilizer materials	1356	1450	1277	1452
Synthetic rubber and plastic materials	1354	1315	1218	1373
Plastics, basic shapes and forms	536	483	419	411
Other chemical products	594	528	436	408
TOTAL	**$6570**	**$6795**	**$6273**	**$6782**
Exports to U.S.	**$4504**	**$4688**	**$4160**	**$4218**
U.S. share	**69%**	**69%**	**66%**	**62%**

Source: Statistics Canada

TRADE BALANCE: Total surplus slips . . .

$ Billions (U.S.)	1991	1990	1989	1988	1987
Total exports	$120.5	$123.7	$117.6	$116.9	$106.0
Total imports	118.1	118.9	118.0	114.5	101.4
Trade balance	2.4	4.8	−0.4	2.4	4.6

. . . as chemical trade deficit worsens

$ Millions (U.S.)	1991	1990	1989	1988	1987
Chemical exports	$6570	$6795	$6273	$6782	$5356
Chemical imports	7230	7220	7091	6596	5436
Chemical trade balance	−660	−425	−818	186	−79

Source: Statistics Canada

PRICES: Synthetic resins are hard hit

Price index, 1986 = 100	1991	1990	1989	% change 1990–91
All commodities	108.6	109.7	109.4	−1.0%
Chemicals and chemical products	115.2	113.8	166.8	1.2
Inorganic industrial chemicals	103.9	103.8	105.8	0.1
Sulfuric acid	110.0	111.1	108.6	−1.0
Chlorine	84.9	93.0	101.4	−8.7
Ammonia	77.2	78.4	84.3	−1.5
Organic industrial chemicals	120.8	118.3	135.0	2.2
Benzene-toluene-xylene	111.4	127.7	125.5	−12.8
Olefins	153.0	133.1	161.2	15.0
Synthetic resins	102.3	111.4	123.0	−8.2
Polyethylene[a]	100.0	115.8	134.9	−13.6
Polystyrene	114.0	127.6	140.7	−10.7
Thermosets	115.1	119.7	125.9	−3.8
Synthetic fibers	105.7	106.6	105.5	−0.8
Agricultural chemicals	115.0	106.9	102.4	7.6
Mixed fertilizers	112.1	105.2	110.8	6.6
Pharmaceuticals	130.6	125.2	119.0	4.3
Paint and varnish	119.7	114.5	111.1	4.5
Soaps and cleansers	118.0	116.0	111.9	1.7
Toilet preparations	116.8	112.9	112.9	3.5
Pigments, lakes, and toners	107.7	106.7	105.8	0.9
Inks	104.4	103.1	101.5	1.3

[a] Includes both high- and low-density polyethylene. **Source:** Statistics Canada

6 FOREIGN CHEMICAL INDUSTRIES - EASTERN EUROPE

In 1991, economies plummeted in all the nations of Eastern Europe and in the former Soviet Union. Industrial production fell 19% in East Europe and 8% in the former U.S.S.R. Coming after a 15% drop in 1990, East Europe's industrial output has fallen by a third since 1989. And in Albania, Europe's least industrialized nation, industrial output shrank 60% last year.

Chemicals did worse in 1991 than industry overall in several countries: Output sank 34% in Bulgaria, 25% in Romania, 14% in Poland, and 10% in the former Soviet Union. And even when they did better than industry overall, chemicals still fell heavily—down 20% in Czechoslovakia, and 16% in Hungary and Yugoslavia.

Transformation of the region's centrally planned systems into market economies based on political democracy—begun in 1989 amid popular enthusiasm—has lost much of its momentum and vigor, because ambitious reform programs failed to bring quick, tangible improvement in living standards. Rising unemployment and inflation, declining consumption, dismantling of communist-era welfare programs, and ethnic conflicts have added to the instability.

The downspin in the former Soviet Union was exacerbated by the waning of central authority, culminating in breakup into independent republics last December. And Yugoslavia's economy and chemical industry, one of the most modern in the region, have been devastated by last year's outbreak of civil war, splitup into separate republics, and imposition of international sanctions.

The outlook is for continued decline in 1992. For example, chemicals may be one of the industries hardest hit by restructuring in the former Soviet republics: Upgrading or closing of uncompetitive chemical plants could bring large drops in output of most major chemical products.

MAN-MADE FIBERS: Output down substantially for all countries but Hungary

Production, thousands of metric tons	1991	1990	1989	1988	% change 1990–91
NONCELLULOSIC FIBERS					
Bulgaria	na	54	66	67	—
Czechoslovakia	96	143	148	147	−33%
Hungary	28	26	32	33	8
Poland	80	113	169	168	−29
Romania	106	138	170	189	−23
Yugoslavia	59[a]	80	88	101	−26
U.S.S.R.	760[a]	955	973	954	−20
TOTAL	**na**	**1509**	**1647**	**1659**	**na**
CELLULOSIC FIBERS					
Bulgaria	na	4[a]	5	5	na
Czechoslovakia	41	57	60	58	−28%
Hungary	2	4	4	4	−50
Poland	26	36	69	77	−28
Romania	38	71	103	108	−46
Yugoslavia	42[a]	68	71	68	−38
U.S.S.R.	415[a]	522	584	601	−20
TOTAL	**na**	**756**	**896**	**921**	—

a Estimate. **na** = not available. **Sources:** PlanEcon Inc., C&EN estimates

PRODUCTION GROWTH: 1991 brought continued declines for chemicals

% annual change in gross output	1991	1990	1989	1988	1987
East Europe[a]					
All industry	−19.1%	−14.7%	−0.5%	2.8%	2.7%
Bulgaria					
All industry	−27.8	−14.1	2.2	5.1	4.2
Chemicals[b]	−34.3[c]	−25.5	3.8	5.8	5.1
Czechoslovakia					
All industry	−21.0	−3.7	0.8	2.1	2.5
Chemicals[b]	−20.0[c]	−8.4	0.7	2.1	3.2
Hungary					
All industry	−21.5	−5.0	−2.5	−0.3	3.5
Chemicals[b]	−16.5[c]	−5.4	−3.1	1.3	5.8
Poland					
All industry	−11.9	−23.3	−0.5	5.3	3.4
Chemicals	−13.5	−25.0	2.6	6.4	4.3
Romania					
All industry	−18.7	−19.8	−2.1	3.1	2.4
Chemicals	−25.0[c]	−32.5	−3.1	3.2	−3.8
Yugoslavia					
All industry	−20.7	−10.3	0.9	−0.7	0.8
Chemicals[d]	−16.2	−13.2	−2.0	2.0	4.0
U.S.S.R.					
All industry[e]	−7.8	−1.2	1.7	3.9	3.8
Chemicals[e]	−10.1[c]	−0.9	1.4	3.8	4.4
All industry[f]	na	−3.1[g]	−0.8	2.4	2.6
Chemicals[f]	na	−5.3[g]	−2.9	2.2	2.7

a Includes Albania, Bulgaria, Czechoslovakia, Hungary, Poland, Romania, and Yugoslavia. **b** Includes rubber industry. **c** Estimated. **d** For basic chemicals, excluding chemical products. **e** Figures based on official Soviet statistics. **f** Figures based on Central Intelligence Agency estimates, giving lower results because of postulated upward bias in official figures. **g** Preliminary figure. **na** = not available. **Sources:** United Nations Economic Commission for Europe and state central statistical bureaus, Central Intelligence Agency, PlanEcon Inc.

AGRICULTURAL CHEMICALS: Fertilizer supplies down throughout Eastern Europe

Thousands of metric tons	1991	1990	1989	1988	% change 1990–91
Czechoslovakia					
Fertilizer supply[a,b]	na	1,506	1,557	1,595	na
Hungary					
Fertilizer supply[a]	na	671	1,221	1,418	na
Poland					
Fertilizer supply[a,b]	1,751	3,029	3,625	3,277	−42%
Pesticide supply[c]	6.5	7.5	20.6	23.4	−13
Romania					
Fertilizer supply[a]	620	1,227	1,159	1,206	−49
Yugoslavia					
Fertilizer supply[a]	733[d]	767	897	1,015	−4
U.S.S.R.					
Fertilizer supply[a]	20,000[d]	21,639	24,482	27,196	−8
Nitrogen[a]	7,700[d]	8,738	9,918	11,587	−12
Phosphate[a,e]	7,500[d]	7,815	8,175	8,556	−4
Potassium[a]	4,800[d]	5,081	6,381	7,044	−6

a Nutrient content basis, as N, P_2O_5, or K_2O. **b** For year ending June 30. **c** On basis of active substance. **d** Estimated value. **e** Includes ground phosphate rock. **na** = not available. **Sources:** Department of Agriculture, Central Intelligence Agency, national central statistical offices

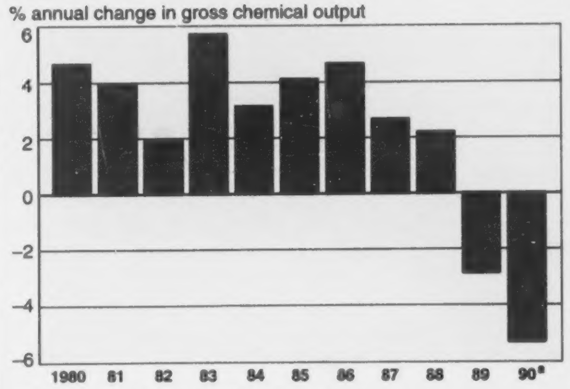
PRODUCTION: Biggest producer, the former U.S.S.R., posted smallest losses

Thousands of metric tons	1991	1990	1989	1988	% change 1990–91
U.S.S.R.					
Sulfuric acid	22,800[a]	27,300	28,276	29,372	−16%
Mineral fertilizers[b]	30,100[a]	31,700	34,254	37,138	−5
Nitrogen[b]	12,100[a]	13,200	14,355	15,815	−8
Phosphate[b,c]	9,200[a]	9,500	9,657	10,013	−3
Potassium[b]	8,800[a]	9,000	10,233	11,300	−2
Plastics	3,975[a]	4,532	4,719	4,634	−12
Sodium hydroxide	2,747[a]	2,973	3,185	3,323	−8
Sodium carbonate	4,006[a]	4,359	4,809	5,098	−8
Synthetic rubber	na	2,400	2,525	2,435	na
Synthetic detergents	na	1,503	1,424	1,301	na
BULGARIA					
Sulfuric acid	na	475	770	780	na
Mineral fertilizers[b]	na	589	724	1,134	na
Nitrogen[b]	na	543	555	984	na
Phosphate[b]	na	47	169	179	na
Synthetic ammonia[d]	na	1,309	1,326	1,342	na
Plastics	180[a]	256	328	363	−30
Sodium hydroxide	na	106	118	124	na
Sodium carbonate	na	1,046	1,153	1,078	na
Synthetic rubber	na	24	25	25	na
Pesticides[e]	na	10	19	18	na
CZECHOSLOVAKIA					
Sulfuric acid	682	1,033	1,142	1,249	−34
Mineral fertilizers[b]	560	877	929	1,025	−36
Nitrogen[b]	357	514	525	596	−31
Phosphate[b,c]	168	257	296	313	−35
Potassium[b,f]	35	106	108	116	−67
Plastics	944	1,174	1,186	1,192	−20
Ethylene	499	619	641	683	−19
Sodium hydroxide	288	335	337	337	−14
Synthetic rubber	45	69	76	79	−35
Pesticides[e]	na	17	18	19	na
HUNGARY					
Sulfuric acid	129	244	482	512	−47
Mineral fertilizers[b]	344	693	897	922	−50
Nitrogen[b]	238	419	513	556	−43
Phosphate[b]	13	56	129	228	−77
Potassium[b,g]	93	218	255	137	−57
Synthetic ammonia[d]	na	444	672	691	na
Plastics	601	603	643	590	−2
Sodium hydroxide[g]	166	193	204	202	−14
Ethylene	254	234	262	264	9
Pesticides[e]	14	24	40	35	−42
POLAND					
Sulfuric acid	1,089	1720	3114	3154	−37
Mineral fertilizers[b]	1396	1769	2590	2718	−21
Nitrogen[b]	1145	1302	1645	1622	−12
Phosphate[b]	251	467	945	962	−46
Synthetic ammonia[d]	na	1768[a]	1941	1923	na
Plastics	593	627	721	723	−5
Sodium hydroxide	311	397	434	444	−22
Ethylene	271	308	322	328	−12
Methanol	na	155	162	168	na
Synthetic rubber	80	103	125	128	−22
Pesticides[e]	17	20	46	45	−15
ROMANIA					
Sulfuric acid	745	1124	1687	1825	−34
Mineral fertilizers[b]	1092	1744	2805	2995	−37
Nitrogen[b]	760[a]	1225[a]	2035	2130	−38
Phosphate[b]	265[a]	425[a]	648	725	−38
Synthetic ammonia[d]	na	1974[a]	2745	2804	na
Plastics	349	473	640	653	−26
Sodium hydroxide	465	552	763	821	−16
Sodium carbonate	478	639	889	918	−25
Ethylene	129[a]	243	332	335	−47
Synthetic rubber	55	102	149	155	−46
Pesticides[e]	18	11	17	na	64
YUGOSLAVIA					
Sulfuric acid	944[a]	1351	1631	1731	−30
Mineral fertilizers[b]	1862[a]	2098	2496	3028	−11
Nitrogen[b]	1663[a]	1842	2103	2487	−10
Phosphate[b]	198[a]	256	393	541	−23
Nitric acid	544[a]	684	730	858	−20
Plastics	534[a]	667	742	724	−20
Sodium hydroxide	146[a]	201	246	437	−27
Detergents	244[a]	295	379	340	−17
Sodium carbonate	144[a]	173	204	214	−17

a Estimated values. **b** Nutrient content basis, as N, P_2O_5, or K_2O. **c** Including production of ground phosphate rock for direct applications and phosphate animal feeds. **d** Nitrogen content. **e** On basis of active substance. **f** Imported potash added to domestically produced nitrogen and phosphate to form multinutrient fertilizer. **g** Including regenerated NaOH. **na** = not available. **Sources:** Central Intelligence Agency, Department of Agriculture, PlanEcon Inc., official national central statistical offices

Chemical output in Soviet Union continued to decline in 1990

% annual change in gross chemical output



a Preliminary data. **Source:** Central Intelligence Agency

6 FOREIGN CHEMICAL INDUSTRIES - **PACIFIC BASIN**

SOUTH KOREA

INDUSTRY TRENDS: Inventories growing

Index, 1985 = 100	1991	1990	1989	1988	% change 1990–91
Chemicals, petroleum, coal, rubber, and plastic products					
Production	194.2	172.9	154.8	150.7	12%
Shipments	205.4	174.4	152.7	146.8	18
Inventories	209.3	176.1	155.4	128.6	19
Industrial chemicals					
Production	222.9	188.6	156.6	149.3	18
Shipments	215.7	184.7	151.6	146.1	17
Inventories	258.6	183.0	164.6	117.6	41
Other chemical products					
Production	223.2	205.5	183.0	171.3	9
Shipments	228.0	209.4	186.5	170.0	9
Inventories	266.6	234.6	195.5	159.5	14
Rubber products					
Production	139.2	144.7	128.1	151.1	−4
Shipments	139.4	143.8	128.1	150.9	−3
Inventories	125.3	122.3	123.1	131.2	2
Plastic products					
Production	168.0	158.9	156.9	159.5	6
Shipments	157.7	151.2	145.5	148.3	4
Inventories	233.0	225.9	193.3	148.3	3
All manufacturing					
Production	202.6	186.5	171.3	166.3	9
Shipments	212.2	191.0	171.6	164.6	11
Inventories	217.4	190.7	162.1	137.6	14

Source: Korean National Statistical Office

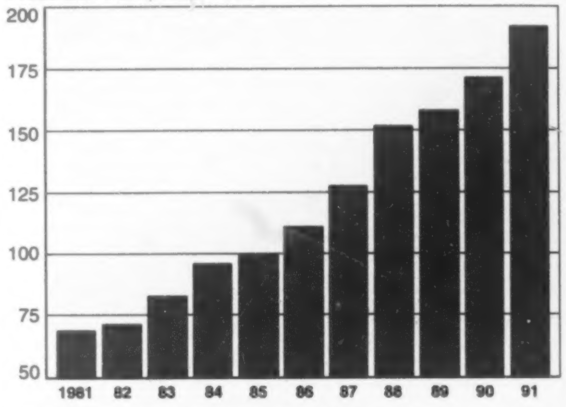
FOREIGN TRADE: Chemicals add to deficit

$ Millions	1991	1990	1989	% change 1990–91
Exports[a]	$71,870	$65,016	$62,377	11%
Imports[b]	81,525	69,844	61,465	17
Trade balance	−9,655	−4,828	912	−100
Chemical exports[a,c]	3,191	2,511	2,050	27
Chemical imports[b,c]	8,289	7,434	7,158	12
Chemical trade balance	−5,098	−4,922	−5,108	−4

Note: Data supplied in U.S. dollars by the Korean government. These values are not recalculated to reflect subsequent changes in monetary exchange rates. **a** Free on board. **b** Includes cost, insurance, freight. **c** Includes chemicals and related products. **Source:** Korean Office of Customs Administration

South Korean chemicals production has risen dramatically in past decade

Production index, 1985 = 100[a]



a Includes chemicals, petroleum, coal, rubber, and plastic products.
Source: Korean National Statistical Office

PRODUCTION: Petrochemicals post gains

Thousands of metric tons	1991	1990	1989	1988	% change 1990–91
Complex fertilizers	1883	1959	1985	2076	−4%
Ethylene	1566	1054	663	609	49
Urea fertilizers	871	883	888	1000	−1
Polyethylene	1164	841	637	572	38
Polyester fibers	780	730	654	593	7
Propylene	855	608	375	351	41
Polypropylene	777	574	530	518	35
Polyvinyl chloride	621	541	477	468	15
Polystyrene	758	592	434	341	28
Benzene	561	381	305	308	47
Synthetic detergents	358	342	297	278	5
Sodium hydroxide	371	332	295	311	12

Source: Korean National Statistical Office

AUSTRALIA

PRODUCTION: Major drop for chemicals

Thousands of metric tons, unless otherwise noted	1991[a]	1990[a]	1989[a]	1988[a]	% change 1990–91
Chemicals					
Superphosphate[b]	1574	2659	na[c]	na[c]	−41%
Sulfuric acid, 100%	986	1464	1878	1818	−33
Ammonium sulfate	215	214	165	179	0
Acetylene[d]	3047	3286	na[c]	na[c]	−7
Plastics and resins	948	985	980	990	−4
Detergents and soap	306	319	na[c]	na[c]	−4
Flexible plastic film, sheets[e]	173	183	na[c]	na[c]	−5
Polyethylene[f]	131	141	na[c]	na[c]	−7
Polypropylene	19	19	na[c]	na[c]	4

a Year ending June 30. **b** Includes double and triple superphosphates expressed in terms of single phosphate (9% P equivalent). **c** Not available prior to July 1989 because of revised commodity classification. **d** Thousands of cubic meters. **e** Includes flexible plates, sheets, foil, and strip of plastics; excludes self-adhesive, floor, wall, and ceiling coverings, vulcanized fibers, plastic foam, and plastics reinforced, laminated, or supported with other materials. **f** Low and high density. **na** = not available. **Source:** Australian Bureau of Statistics

FOREIGN TRADE: Chemical exports growing

$ Millions	1991[a]	1990[a]	1989[a]	% change 1990–91
Exports[b]	$41,193	$38,685	$34,131	6%
Imports[c]	38,416	40,311	36,959	−5
Trade balance	2,777	−1,626	−2,828	—
Chemical exports[b]	1,082	971	828	11
Medicinal products	248	209	183	19
Chemical imports[c]	3,986	4,080	3,894	−2
Plastics and polymers[d]	731	810	838	−10
Medicinal products	740	644	545	15
Chemical trade balance	−2,904	−3,109	−3,066	7

Note: Statistics for all years converted from Australian to U.S. dollars on basis of 1991 conversion rate of $1.00 = $A1.2734. **a** Year ending June 30. **b** Free on board. **c** Values for customs purposes, free-on-board basis. **d** Includes polymer and copolymerization products, and condensation, polycondensation, and polyaddition products. **Sources:** Australian Department of Foreign Affairs & Trade, Australian Treasury Department

CHINA

PRODUCTION: Healthy gains in most areas, especially plastics and pharmaceuticals

Thousands of metric tons	1991[a]	1990	1989	1988	% change 1990–91
Synthetic ammonia	21,973	21,251	20,675	19,725	3%
Fertilizer[b]	19,880	18,790	18,547	17,670	6
Sulfuric acid[c]	13,140	11,967	11,408	10,981	10
Sodium hydroxide[c]	3,533	3,338	3,211	2,925	6
Sodium carbonate	3,890	3,799	2,983	2,593	2
Plastics	2,640	2,249	1,973	1,552	17
Man-made fibers	1860	1655	1466	1284	12%
Synthetic detergents	1430	1516	1431	1290	−6
Ethylene	1746	1572	1405	1231	11
Pesticides	250	228	224	202	10
Pharmaceuticals	195	172	196	194	13
Synthetic rubber	335	316	289	251	6

a Preliminary. b Nutrient content. c 100%. **Sources:** State Statistical Bureau of the People's Republic of China, *China Economic News*, Central Intelligence Agency, *China Statistics Monthly*

CHEMICAL IMPORTS: Up sharply in 1991

$ Millions[a]	1991	1990	1989	1988	% change 1990–91
Organic chemicals	$1884	$1131	$1405	$1701	67%
Inorganic chemicals	209	215	469	448	−3
Dyeing, tanning, coloring materials	345	244	226	237	41
Medicinal and pharmaceutical products	490	395	311	384	24
Fertilizers[b]	3229	2605	2364	2335	24
Plastic materials, resins, cellulose esters and ethers	2378	1498	2206	3558	59
TOTAL[c]	**$9277**	**$6648**	**$7556**	**$9139**	**40%**

Note: Data supplied in U.S. dollars by the Chinese government. These values are not recalculated to reflect subsequent changes in monetary exchange rates. a Includes cost, insurance, and freight. b Manufactured. c For all chemicals and related products. **Source:** General Administration of Customs of the People's Republic of China

CHEMICAL EXPORTS: Rose slightly

$ Millions[a]	1991	1990	1989	1988	% change 1990–91
Organic chemicals	$ 911	$ 838	$ 690	$ 575	9%
Inorganic chemicals	913	842	794	762	8
Dyeing, tanning, coloring materials	335	366	288	229	−8
Medicinal and pharmaceutical products	743	622	549	468	19
Essential oils, perfumes, cleansing materials	220	319	235	183	−31
Explosives, pyrotechnic products	156	211	244	298	−26
TOTAL[b]	**$3818**	**$3730**	**$3201**	**$2897**	**2%**

Note: Data supplied in U.S. dollars by the Chinese government. These values are not recalculated to reflect subsequent changes in monetary exchange rates. a Free on board. b For all chemicals and related products. **Source:** General Administration of Customs of the People

TAIWAN

INDUSTRY TRENDS: Fibers lead growth

Industrial production indexes, 1986 = 100	1991	1990	1989	1988	% change 1990–91
All manufacturing	125.3	116.7	119.0	115.4	7%
Chemical materials	136.6	119.1	110.1	108.0	15
Basic chemicals	126.7	114.8	102.9	94.4	10
Petrochemicals	102.3	94.8	92.0	96.8	8
Fertilizers	115.9	114.1	111.3	113.4	2
Synthetic fibers	172.4	142.7	126.7	113.5	21
Plastics and resins	166.0	139.1	127.3	122.8	19
Chemical products	152.5	139.8	129.1	125.7	9

Source: Taiwan Ministry of Economic Affairs

FOREIGN TRADE: Chemical deficit grows

$ Millions	1991	1990	1989	% change 1990–91
Exports[a]	$ 76,177	$ 67,293	$ 65,241	13%
Imports[b]	62,854	54,714	51,514	15
Trade balance	13,323	12,579	13,727	6
Chemical exports[a,c]	6,743	5,718	5,313	18
Chemical imports[b,c]	9,344	7,621	7,301	23
Chemical trade balance	−2,601	−1,903	−1,988	−37

Note: Statistics for all years converted from New Taiwan dollars (NT$) to U.S. dollars on basis of 1991 conversion rate of $1.00 =NT$26.8. a Free on board. b Includes cost, insurance, and freight. c Includes chemicals, chemical products, and plastic and rubber products. **Sources:** Taiwan Council for Economic Planning & Development, Taiwan Ministry of Finance Department of Statistics

PRODUCTION: Mixed results for chemicals

Thousands of metric tons, unless otherwise noted	1991	1990	1989	1988	% change 1990–91
Polyester[a]	1457	1290	1193	1100	13%
Polyvinyl chloride	978	921	805	779	6
Terephthalic acid[b]	986	798	583	495	24
Ethylene	709	776	766	852	−9
Vinyl chloride	595	665	662	708	−11
Sulfuric acid	776	658	768	664	18
Ammonium sulfate	478	509	524	484	−6
Propylene	389	398	398	441	−2
Acrylonitrile-butadiene-styrene	472	384	311	301	23
Oxygen[c]	364	370	352	350	−1
Polyethylene[d]	334	360	344	390	−7
Styrene	368	355	301	331	4
Calcium superphosphate	363	354	352	315	2
Ammonia, anhydrous	296	263	246	339	13
Paints	246	239	214	247	3
Hydrochloric acid	265	234	217	255	13
Xylene	207	221	213	164	−6
Urea	206	229	237	306	−10
Dioctyl phthalate	192	188	179	167	2
Ethylene glycol	179	178	216	197	1

a Filament and staple. b Pure terephthalic acid. c Millions of cubic meters. d Low and high density. **Source:** Taiwan Council for Economic Planning & Development

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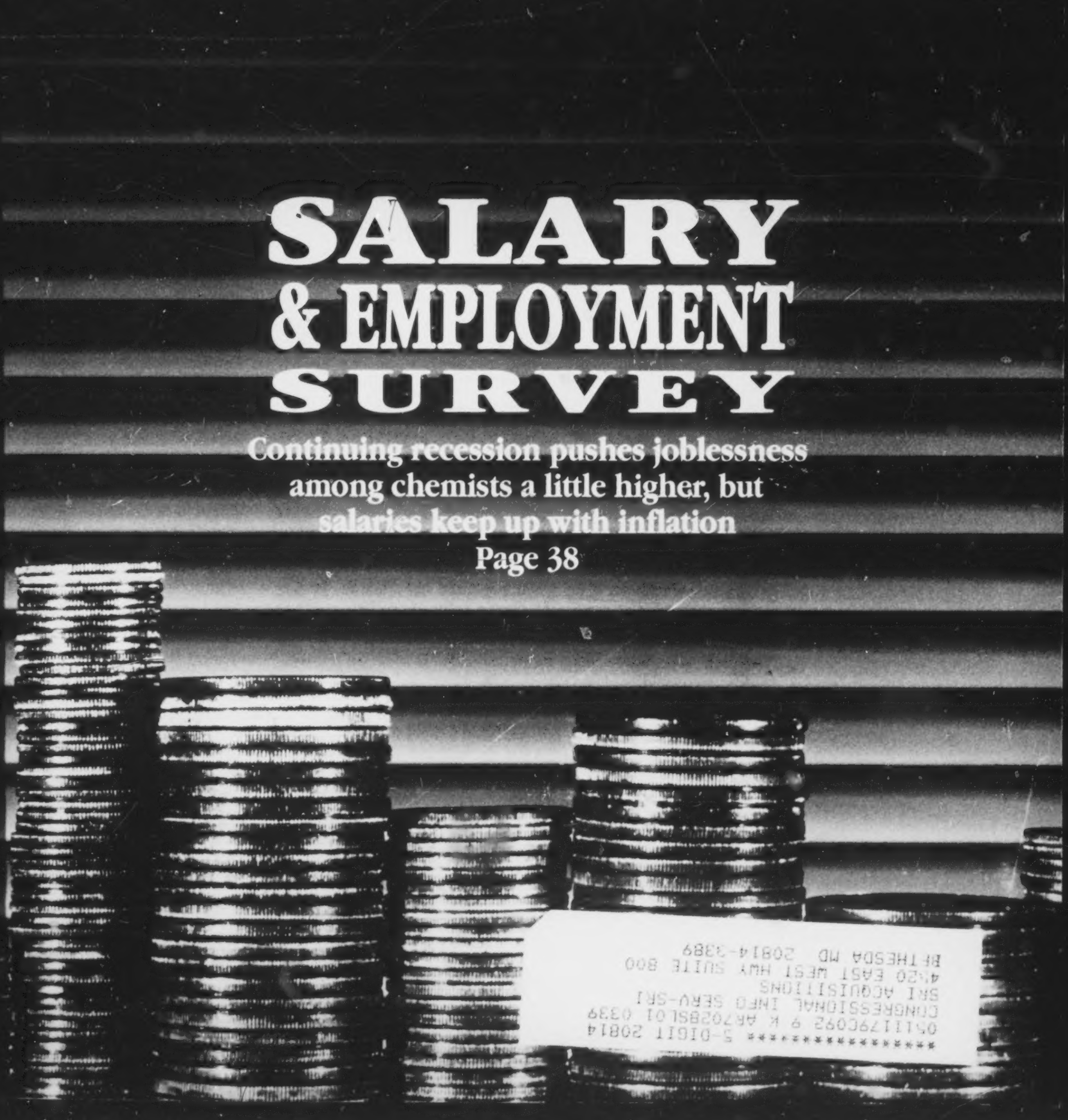
CHEMICAL & ENGINEERING NEWS
C&EN
JULY 13, 1992

PVC PRODUCERS STRUGGLE TO MAINTAIN PLANT OPERATING RATES PAGE 15



SALARY & EMPLOYMENT SURVEY

Continuing recession pushes joblessness among chemists a little higher, but salaries keep up with inflation
Page 38

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CHEMICAL & ENGINEERING NEWS

C&EN

JULY 13, 1992

NEWS OF THE WEEK

- Fullerenes C_{60} and C_{70} have been found in an ancient carbon-rich rock from Russia, the first evidence that these compounds occur in nature. **Page 6**
- U.S. appellate courts overturn EPA regulations allowing low levels of carcinogenic pesticides in foods, and throw out OSHA standards for workplace exposure to 428 toxic substances. **Page 7**
- NASA launches spacecraft to gather data on energetic particles from the Milky Way galaxy and the Sun, and to probe the origin of anomalous cosmic rays. **Page 7**
- People who drink chlorinated surface water are more at risk for developing bladder and rectal cancer than those who do not, according to a recent study. **Page 7**
- Hoechst and Petrofina plan to swap U.S polymer assets producing high-density polyethylene and dimethyl terephthalate. **Page 8**

COVER: Photo by Clark Dunbar, Uniphoto Picture Agency

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ISSN 0009-2347

BUSINESS

Market for polyvinyl chloride shows some signs of recovery following low demand of past few quarters, but producers now face new capacity and an expected summer slowdown. **Page 15**

European Chemical Industry Council implements plan to transfer environmental and energy-saving technology to chemical industries in East European countries. **Page 17**

GOVERNMENT

A proposed strategic plan for NIH was wrestled with at a recent meeting by a task force of working scientists and research administrators, and is expected to be ready by summer's end. **Page 20**

Superconducting Super Collider is fighting to stay alive, with the House voting to cut SSC funding from the fiscal 1993 budget and the upcoming Senate vote likely to be close. **Page 21**

SCIENCE/TECHNOLOGY

Silico-titanates, new materials that extract cesium-137 from solutions with high salt concentrations, show promise for cleaning up radioactive wastes. **Page 26**

Centers for Disease Control is offering grants for development of new or improved technology to measure concentrations of lead in whole blood. **Page 27**

EDUCATION

Test aid relieves exam anxiety for college chemistry students—for a price of points, they can scratch off coating to reveal clues to solving examination problems. **Page 37**

SALARY SURVEY

Lingering recession continues to hurt the job market for chemists, with the 1.9% jobless rate at highest level since 1983; conversely, salary increases have more than kept up with inflation. Page 38

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1155—16th St., N.W., Washington, D.C. 20036

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Published by
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

Triphosgene warning

Triphosgene is a conveniently used solid-phase form of phosgene sold by Aldrich Chemical Co. Inc. This reagent is finding wide use in synthetic applications involving formation of ureas, chloroformates, isocyanates, and other related compounds. As a solid with low volatility, it is much safer to handle than phosgene itself and has been marketed for its excellent transport, storage, and manipulation characteristics (for example, see the back cover of *J. Org. Chem.*, June 21, 1991).

Last autumn, Aldrich was selling research quantities of triphosgene in paraffin-sealed bottles packed in vermiculite inside sealed metal cans. We were surprised when, upon puncturing the top of the can with a can opener, there was a fairly loud hiss that lasted for approximately two seconds. Subsequent examination of the bottle revealed that the cap had been cracked. We suspect that the escaping gas was phosgene, which had been formed by reaction of triphosgene with small amounts of water trapped in the vermiculite.

Phosgene is a well-known war gas. The lowest published concentration that is lethal to humans (inhalation) is 50 ppm for five minutes. Short-term exposure limits have been established at 1 ppm for five minutes. This compound is especially insidious because severe symptoms can arise even if the exposed person does not smell the gas. Although the metal can contained standard warnings concerning the toxicity and respiratory hazards of triphosgene, there were no indications that the contents of the can were packaged in such a way that might allow pressure to develop.

Our phone call to Aldrich revealed that two other similar incidents had occurred within the past two years, and that cans that are not opened shortly after receipt could develop significant pressures. Because of these problems, Aldrich now seals its triphosgene bottles in plasticized aluminum pouches inside vermiculite-filled cans. These cans are now marked, "Keep Refrigerated." Cans of triphosgene purchased either last year or earlier this year, and which do not contain the "Keep Refrigerated" warning, should be treated with extreme caution.

Mark D. Hollingsworth
Department of Chemistry
Indiana University
Bloomington

Aldrich introduced triphosgene as a convenient phosgene substitute. We have been selling this product in research quantities since 1987. During that time, we have made several packaging changes to enhance the safety factor during shipping and handling. We take our customers' complaints and concerns seriously and attempt to incorporate all appropriate suggestions into our packaging program. We believe that the best warning advice is to state on the bottle and package: "Open and handle only with gloves in hood."

We will implement this change immediately and notify our past customers. As you are aware, no simple warning will adequately cover all hazards and situations. Therefore, we strongly recommend that individuals who intend to work with this or any chemical with which they are not totally familiar, should first read the material safety data sheet and then handle the chemical with the proper recommended equipment and protection in place.

We appreciate Mark Hollingsworth's efforts in bringing this matter to the attention of the chemical community. We at Aldrich operate under the philosophy of always striving to offer the most versatile reagents available in the safest manner possible.

Kenneth J. TerBeek
Manager, Environmental, Safety, Health, and Regulatory Affairs
Aldrich Chemical Co. Inc.
Milwaukee

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Job Market for Chemists Weakens, Salaries Hold Up Quite Well

ACS survey puts jobless rate for chemists at highest level in nine years, indicates above-inflation salary gains

Michael Heylin, C&EN Washington

This year's American Chemical Society survey of the salaries and employment status of its members has produced the usual mind-boggling array of data that many chemists apparently like to pore over either out of curiosity or in a quest for nuggets of information to support their own career aspirations.

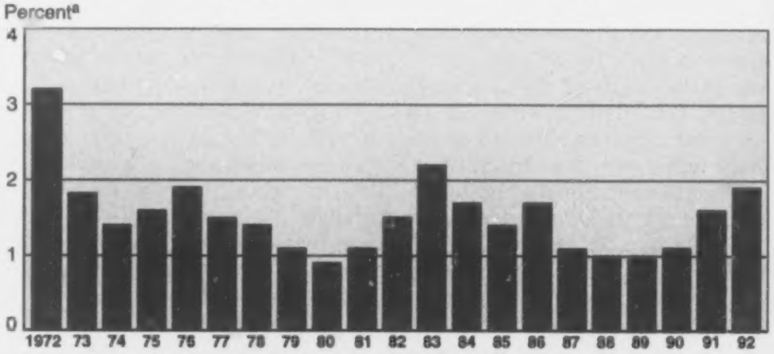
The survey analyzes salaries of chemical professionals seemingly every which way. These include by gender, highest degree, percentile, years since receiving B.S. degree, age, type of employer, size of employer, and work function. The study is equally diligent in dissecting the employment situation.

But the bottom line of this year's survey, taken as of March 1, is confirmation of what chemists have known for some time—that the lingering recession has made the employment situation for chemical professionals less secure than it has been in almost a decade. On the brighter side, the survey reveals that salary increases for chemists over the past year more than kept up with inflation.

Of those responding to the survey, 1.9% were without jobs, but seeking employment. This is the highest level of unemployment in the chemical profession since 1983, when it was 2.2%.

The survey also indicates a median salary for Ph.D.s that is 3.4% higher than a year earlier. Bachelor-level chemists posted a 4.3% gain. Chemists with M.S. degrees did a little better, with a boost of 5.5%. These gains exceeded the 3.2% rise in the consumer price index for urban consumers between March 1991 and March 1992.

The survey this year involved mailing questionnaires to 20,000 ACS members living in the U.S. who were not more than 70 years old and neither students nor on retired status. It was directed by Joan S. Burrelli of ACS's Office of Professional Services.



Number of unemployed chemists moves up again

a Unemployed, but seeking employment, as of March 1 each year. **Source:** ACS survey

Slightly more than 12,000, or 60%, responded to the survey. Of these, 62% were employed by industry, 25% were academics, 8% were government employees, and 5% worked for a variety of other organizations. By degree, 59% held Ph.D.s, 24% bachelor's, and 17% master's. By gender, 20% were women. By race 87.6% were white, 8.6% Asian, 1.5% Hispanic, 1.3% black, 0.4% Native American, and 0.6% "other."

Government offers most stable employment for chemists

	Employed[a] Full time	Employed[a] Part time	Postdoc	Seeking employment
EMPLOYER				
Industry	96.6%	0.9%	0.3%	2.1%
Academia	88.0	3.1	7.6	1.3
Government	94.1	2.0	3.1	0.9
Other nonacademic	81.0	12.9	2.4	3.7
MOST RECENT WORK				
Production	97.5	0.6	0	1.9
R&D management	97.3	1.0	0.1	1.6
General management	97.1	1.0	0.1	1.7
Marketing	95.2	1.3	0	3.5
R&D	91.1	1.2	5.8	1.9

a As of March 1, 1992. **Source:** ACS survey

As has been the case for many years, the rate of unemployment among ACS members is apparently well below more general indicators of joblessness. The 1.9% rate revealed by the latest survey for March 1 of this year compares with government data indicating a 7.3% unemployment rate for all civilian workers and a 2.9% rate for those with a managerial or professional specialty.

However, even relatively slight year-to-year movements in the unemployment rate determined by ACS's annual surveys indicate considerable change in the actual job situation for chemists. During prosperous times the ACS fig-

Women, minorities, and Ph.D.'s are least likely to be employed full time

	Chemists								Chemical engineers
		By sex		By highest degree			By minority status		
Employment status[a]	Total	Men	Women	B.S.	M.S.	Ph.D.	Minority[b]	Nonminority	
Employed full time	91.8%	93.3%	86.0%	92.7%	92.7%	91.2%	88.2%	92.3%	91.7%
Employed part time	2.2	1.4	5.4	2.1	2.6	2.2	1.4	2.3	3.4
Postdoctoral or fellowship	2.4	2.2	3.1	0.2	0.2	3.9	7.6	1.6	0.3
Unemployed									
Seeking employment	1.9	1.8	2.4	2.3	2.0	1.7	1.9	1.9	2.8
Not seeking employment	1.7	1.4	3.1	2.6	2.5	1.1	0.9	1.8	1.8

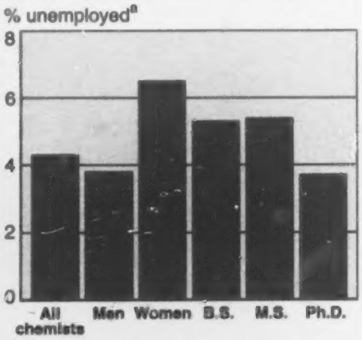
a As of March 1, 1992. b Black, Spanish/Hispanic, Native American, Alaskan native, Asian, Pacific Islander, or other. **Source:** ACS survey

Percentage of chemists employed full time is at lowest level in the decade

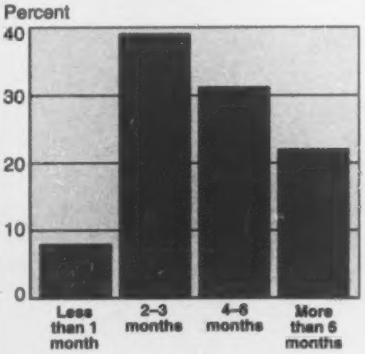
Employment status[a]	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982
Employed full time	93.4%	94.0%	95.2%	95.3%	95.4%	95.4%	94.8%	95.2%	93.7%	93.5%	94.9%
Employed part time	2.2	1.8	1.4	1.5	1.6	1.5	1.5	1.5	1.7	1.7	1.4
Postdoctoral or fellowship	2.4	2.6	2.2	2.2	2.0	2.0	2.0	1.9	2.9	2.6	2.2
Unemployed	1.9	1.6	1.1	1.0	1.0	1.1	1.7	1.4	1.7	2.2	1.5

a As of March 1, 1992; excludes chemists who are not employed but not seeking employment. **Source:** ACS survey

More than 4% of chemists jobless sometime in 1991...



...nearly one in four for more than six months



a Unemployed at sometime between March 1, 1991, and March 1, 1992. **Source:** ACS survey

ure hovers very close to 1.0%. The lowest it has been in the past 20 years was 0.9%, in 1980. The recession in 1972, which affected the chemical profession very badly, pushed it to a seemingly still quite modest 3.2%. This year's 1.9% reflects a considerable, but less severe, downturn for the chemical professional—as did the 2.2% rate for 1983, another recession year.

The survey also indicates that 4.3% of respondents were jobless at some time between March 1991 and March 1992. This compares with 3.1% during the previous 12 months. Of the unemployed between March 1991 and March 1992, slightly more than half, 53%, were out of work for more than three months. Of women respondents, 6.5% were unemployed at some time during these 12 months. This compares with 3.5% for men.

Other data from the survey also confirm a generally weaker employment situation for women. For instance, only 89% of women either with a job or seeking a job were employed full time as of March 1. This compares with almost 95% of the men. Significantly more women than men were unemployed, 2.4% verus 1.8%. And a higher proportion of women than men were employed part time—5.4% compared to 1.4%.

By degree, B.S. chemists were considerably more likely to be unemployed, 2.3%, than were Ph.D.s, 1.7%. By previous employer, those from industry were most likely to be jobless, 2.1%. This compares with 0.9% of government workers and 1.3% of academics.

The overall message from the salary data from the new survey, as from previous surveys, is that those who want to work in chemistry but also want to maximize their salaries should plan for a long career, earn a Ph.D., obtain a job in industry, and manage something. It also helps to be male, but less so than it once did, especially for younger workers. This scenario reflects the major determinants of chemists' salaries—experience, highest degree, type of employer, job function, and gender.

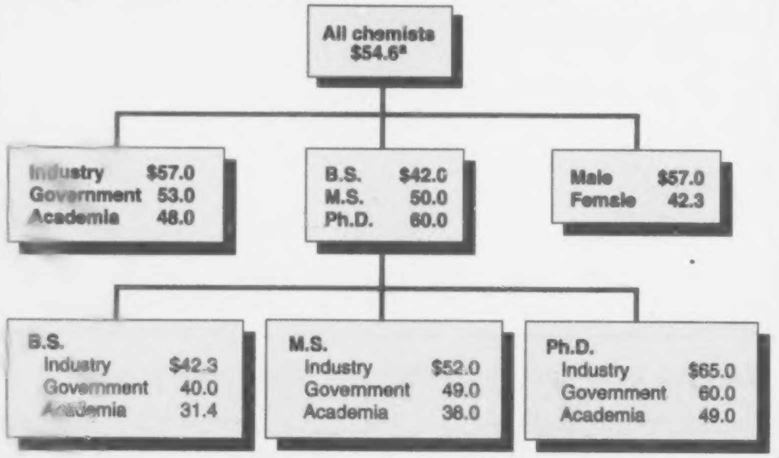
These factors overlap considerably. For instance, older ACS members are much more likely to be Ph.D.s than are younger members. Women chemists as a group are younger, less experienced, and less likely to hold advanced degrees than their male colleagues—all factors that depress their overall median salary.

The salary data in the survey, unless otherwise stated, are medians of the base salary from the principal job of respondents employed full time. They exclude bonuses, overtime, and additional professional income, such as from consulting. Medians are used because they are distorted less by the relatively few extremely high salaries than are means. For instance, the mean salary for all B.S. respondents to the survey was about $5000 higher than the median. This differential at the M.S. and Ph.D. levels was about $4000.

The gross salary medians indicate that Ph.D.s earn $60,000, 43% more than B.S. chemists, who earn $42,000; that chemists in industry earn almost 19% more than academics, $57,000 versus $48,000; and that men earn a hefty 35% more than women, $57,000 versus $42,300.

However, more detailed breakdowns reveal less extreme differences. For instance, the median salary of $65,000 for industrially employed Ph.D. chemists is 53% higher than the $42,300 median for bachelor-level chemists also employed in industry.

Chemists better paid by industry at all degree levels



a Median base annual salaries in thousands of dollars as of March 1, 1992. **Source:** ACS survey

Median salaries for chemists reach $60,000 for those with Ph.D.s, $50,000 for master's

$ Thousands	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	% annual change 1991–92	1987–92	1982–92
CHEMISTS' MEDIAN SALARIES[a]														
B.S.	$42.0	$40.3	$39.0	$37.0	$35.4	$33.5	$33.0	$32.0	$30.9	$30.0	$28.5	4.2%	4.6%	4.0%
M.S.	50.0	47.4	45.0	43.0	41.0	39.0	37.9	36.0	34.0	33.0	31.6	5.5	5.1	4.7
Ph.D.	60.0	58.0	55.0	52.5	50.0	47.7	47.8	44.0	42.0	40.0	37.5	3.4	4.7	4.8
All chemists	54.6	52.0	49.8	47.3	45.0	42.5	42.5	40.0	38.0	36.0	34.7	5.0	5.1	4.6

a. Base annual salary of chemists employed full time as of March 1, 1992. **Source:** ACS survey

Top 10% of Ph.D. industrial chemists earn over $100,000 after working about 20 years

Median salary, $ thousands[a]	Years since B.S. degree 0 to 1	2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
INDUSTRIAL CHEMISTS											
B.S.											
90%	$36.0	$39.7	$48.6	$58.0	$65.0	$83.0	$ 86.0	$ 87.0	$109.6	$120.0	$70.0
75%	32.0	35.2	42.0	49.4	57.5	65.0	70.0	72.0	80.0	85.0	55.0
50%	29.0	32.0	37.0	42.3	48.0	54.5	56.0	58.0	60.0	65.0	42.4
25%	22.3	27.8	32.0	37.0	41.0	45.0	46.5	48.6	50.0	54.0	35.0
10%	20.3	24.2	28.0	32.0	34.7	38.1	39.0	36.0	41.0	40.0	29.2
M.S.											
90%	—	—	49.0	65.0	76.0	81.0	89.0	92.9	105.3	88.0	79.7
75%	—	—	44.9	55.0	62.0	68.0	70.0	67.0	83.0	79.7	64.0
50%	—	—	40.0	46.0	53.2	59.4	60.0	59.9	65.0	67.8	52.0
25%	—	—	36.1	41.0	46.1	49.0	50.0	48.3	53.0	55.0	43.0
10%	—	—	33.0	36.0	40.0	41.7	45.0	42.5	43.0	48.0	36.3
Ph.D.											
90%	—	—	58.0	70.0	80.5	95.6	106.0	130.0	125.0	126.0	97.0
75%	—	—	55.0	62.0	72.0	81.4	91.5	96.0	96.0	103.0	80.0
50%	—	—	52.0	56.9	63.5	70.0	76.0	79.0	80.0	85.0	65.0
25%	—	—	48.1	52.0	58.0	60.3	66.8	67.0	67.0	67.5	56.0
10%	—	—	44.0	47.0	51.0	53.0	58.8	56.8	56.1	54.0	49.8

How to read this table: Using, as an example, industrial B.S. chemists two to four years after they have received their B.S. degree, 90% of these chemists have annual base salaries of $39,700 or less; 75% have annual base salaries of $35,200 or less, 50% have annual base salaries of $32,000 or less, 25% have annual base salaries of $27,800 or less, and 10% have annual base salaries of $24,200 or less, as of March 1, 1992. **a** As of March 1, 1992. **Source:** ACS survey

Salaries of women chemists in industry seem to plateau after about 15 years on the job

Median salary, $ thousands[a]		Years since B.S. degree									
		2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
CHEMISTS EMPLOYED FULL TIME IN INDUSTRY											
Total											
B.S.		$32.0	$37.0	$42.3	$48.0	$54.5	$56.0	$58.0	$ 60.0	$ 65.0	$42.4
M.S.		35.0	40.0	46.0	53.2	59.4	60.0	59.9	65.0	67.8	52.0
Ph.D.		—	52.0	56.9	63.5	70.0	76.0	79.0	80.0	85.0	65.0
Sex											
Men	B.S.	31.7	38.2	43.6	48.4	56.4	57.8	59.1	63.0	65.4	45.7
	M.S.	—	40.0	46.8	54.0	59.7	60.5	60.0	65.5	68.8	54.0
	Ph.D.	—	52.0	57.0	63.5	70.3	76.8	80.0	80.0	85.0	67.0
Women	B.S.	32.5	36.0	39.5	46.0	44.0	48.0	50.0	—	—	37.0
	M.S.	—	40.0	43.5	52.7	55.9	56.0	50.0	—	—	45.0
	Ph.D.	—	51.5	55.6	63.7	65.0	70.0	—	—	—	58.0
Work function											
General management	B.S.	—	39.0	49.4	56.5	58.5	80.4	67.0	—	—	56.5
	M.S.	—	—	—	60.6	62.5	—	—	—	—	63.0
	Ph.D.	—	—	—	69.7	90.0	81.5	89.1	101.0	—	83.5
R&D management	B.S.	—	38.0	47.5	55.5	70.0	—	70.7	—	—	56.9
	M.S.	—	—	58.0	64.5	65.0	74.1	72.0	—	—	67.0
	Ph.D.	—	—	66.6	72.0	81.0	92.0	85.0	91.0	103.5	81.0
Basic research	B.S.	34.6	36.3	39.9	45.0	—	—	—	—	—	38.6
	M.S.	—	40.8	44.9	47.5	—	—	—	—	—	45.0
	Ph.D.	—	53.0	58.2	64.5	69.5	75.0	80.8	75.0	—	61.1
Applied research	B.S.	33.0	37.5	42.5	49.0	53.2	53.3	54.5	56.7	—	42.0
	M.S.	—	41.8	45.0	52.5	56.0	52.5	60.0	65.0	—	49.7
	Ph.D.	—	51.0	56.0	62.0	65.0	70.0	72.0	75.5	68.8	60.0
Production	B.S.	—	40.0	48.0	53.5	65.0	—	—	—	—	50.0
	M.S.	—	—	49.5	59.5	66.6	—	—	—	—	55.1
	Ph.D.	—	—	53.9	—	—	70.5	68.8	—	—	66.3
Marketing	B.S.	31.0	35.8	41.1	42.0	50.0	46.8	—	53.7	—	39.3
	M.S.	—	38.3	39.0	55.0	54.0	—	—	—	—	48.0
	Ph.D.	—	—	51.3	54.5	—	69.1	—	—	—	57.6

Note: Where no salary data are shown, sample is too small (less than 15) to provide meaningful figure. a As of March 1, 1992. **Source:** ACS survey

But when the comparison is between those of the same age, this salary differential drops to about 34%.

Similarly, the seeming 35% salary advantage for male chemists is substantially a result of their greater average age, higher degree level, and more experience. After adjustment for these factors, this salary differential generally falls into the 5 to 15% range.

A more detailed analysis of data from chemists employed by industry indicates that the median salaries of men and women Ph.D.s remain essentially the same up until about age 45 (15 to 19 years after the B.S.). For older age groups, the salary medians tend to plateau for women. But for men they show sizable further gains. The pattern is similar for industrial M.S. and B.S. chemists, with salary differences between men and women becoming increasingly apparent in the older age groups.

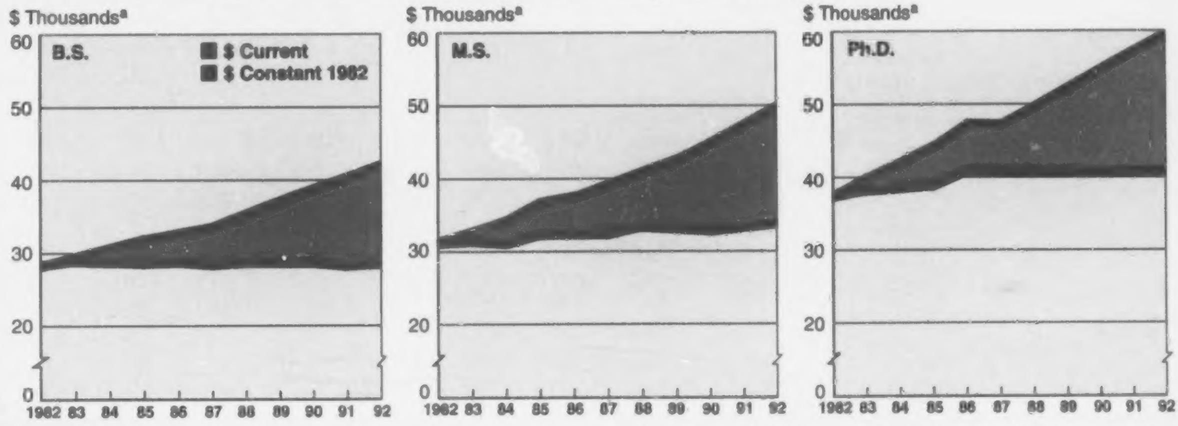
The analysis of industrial salaries by

Salary gap between men and women chemists is generally smaller in government

Mean salary, $ thousands[a]	B.S.				M.S.				Ph.D.			
	All chemists	Men	Women	Women as % of men	All chemists	Men	Women	Women as % of men	All chemists	Men	Women	Women as % of men
EMPLOYER												
Private industry	$47.4	$50.5	$43.3	86%	$55.5	$57.3	$54.3	95%	$71.1	$72.4	$63.8	88%
Academia	34.6	35.7	34.2	96	39.4	42.3	35.7	85	53.8	55.9	45.4	81
Government	42.5	44.5	42.5	96	49.2	52.4	45.8	87	61.7	63.1	57.3	91
Other	53.4	60.0	41.6	78	59.5	63.6	47.0	74	71.2	73.3	53.3	73

a As of March 1, 1992; to facilitate comparison, women's salaries are adjusted for the difference in average length of experience between them and men. **Source:** ACS survey

Constant-dollar salaries for B.S. chemists have stagnated for past 10 years



Note: Average salary increases for individual chemists have been larger because of increasing experience. a Median base annual salary for chemists employed full time as of March 1 of each year. **Source:** ACS survey

job function confirms that general managers and R&D managers have the edge. For Ph.D.s, medians of $83,500 for general managers and $81,000 for R&D managers compare with $60,000 for Ph.D.s in applied research and $61,100 for those in basic research. Part of this differential between management and research may be due to age. Older Ph.D.s tend to move out of research—at least [illegible]&D management. Those who do stay at the bench apparently don't do too badly. For instance, Ph.D. chemists still in basic research 30 to 34 years after receiving their B.S. degrees have a median salary of $80,800. This compares with $89,100 for their contemporaries in general management.

The latest survey also indicates that the size of industrial employers had an impact on salaries. Larger firms apparently pay more. Companies with 25,000 or more employees pay their chemists about 15% more than do firms with less than 500 employees.

The difference in median salaries for Ph.D.s in industry, $65,000, and in academia, $49,000, is also deceptively large. A considerable number of academics have nine- or 10-month contracts and earn additional income from their summer activities that is not included in the ACS data. Also, the median salary of $85,000 for full professors at Ph.D.-granting institutions compares well with that for Ph.D. managers in industry.

Data from the survey indicate that professional income in addition to basic salary from principal job—such as from bonuses, overtime, summer work, or consulting—averaged $6600 for all respondents. However, distribution of this income was very skewed. More than 40% of respondents received no such income, whereas those in the highest 10 percentile received $15,500 or more. The median was $1500. The mean for B.S. chemists was $5200. But the median was only $500. Such income was higher for doctoral chemists with a mean of $7600 and a median of $2100.

In general, the salaries of chemists employed in government fall between those of their colleagues in industry and academia—if somewhat closer to the industry level.

Biggest salary gains for chemists come in first 20 years of career

Median salary, $ thousands[a]	Years since B.S. degree									Overall median
	2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	
ALL CHEMISTS[a]	$31.5	$40.0	$48.0	$55.0	$60.0	$63.4	$63.0	$66.0	$66.0	$54.6
By sex										
Male	31.3	41.5	50.0	55.5	61.0	66.0	65.0	68.0	68.9	57.1
Female	32.0	38.0	42.0	50.8	50.0	49.0	50.0	51.2	49.7	42.4
By degree										
B.S.	31.2	36.9	42.0	47.0	52.0	55.6	55.7	60.0	62.2	42.0
M.S.	—	39.0	45.0	52.7	54.4	56.0	53.0	58.0	58.0	50.0
Ph.D.	—	50.0	53.5	59.7	63.7	68.0	68.0	70.0	70.0	60.0
By employer										
Industry	32.2	42.0	52.0	59.0	64.2	70.0	71.0	73.0	75.0	57.0
Government	—	37.0	42.5	49.3	51.5	60.0	62.2	68.7	64.9	53.0
Academia	—	31.1	36.5	41.0	45.0	51.6	55.0	57.0	60.0	47.9

a As of March 1, 1992. **Source:** ACS survey

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In industry, managers have large salary edge

Median salary, $ thousands[a]	By degree B.S.	M.S.	Ph.D.
R&D management	$56.9	$66.0	$80.9
General management	56.4	63.0	83.5
Marketing	50.0	55.1	66.3
Applied research	42.0	49.6	60.0
Production	38.5	47.8	57.6
Basic research	38.5	45.0	61.1

[a] As of March 1, 1992. **Source:** ACS survey

Bigger industrial firms tend to pay chemists more

Median salary, $ thousands[a]	By degree B.S.	M.S.	Ph.D.
NUMBER OF EMPLOYEES			
Less than 500	$40.0	$50.0	$60.0
500 to 2499	42.5	49.7	62.5
2500 to 9999	44.0	51.6	66.0
10,000 to 24,999	46.0	53.0	65.0
25,000 or more	46.6	56.0	69.9

[a] As of March 1, 1992. **Source:** ACS survey

Full professors at top schools do well

Median salary, $ thousands[a]	9- to 10-month contracts: Non-Ph.D. school	Ph.D. school	11- to 12-month contracts: Non-Ph.D. school	Ph.D. school
Full professor	$49.5	$61.0	$67.3	$85.0
Associate professor	38.2	43.3	56.9	54.6
Assistant professor	32.0	37.2	40.9	45.0

[a] As of March 1, 1992. **Source:** ACS survey

The full report on this year's ACS survey, "Salaries 1992," will be available in August at $150 per copy. It can be purchased from the ACS Distribution Office, Room 210, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036.

Questions or comments should be directed to Joan Burrelli at (202) 872-4433. ☐

CHEMICAL & ENGINEERING NEWS

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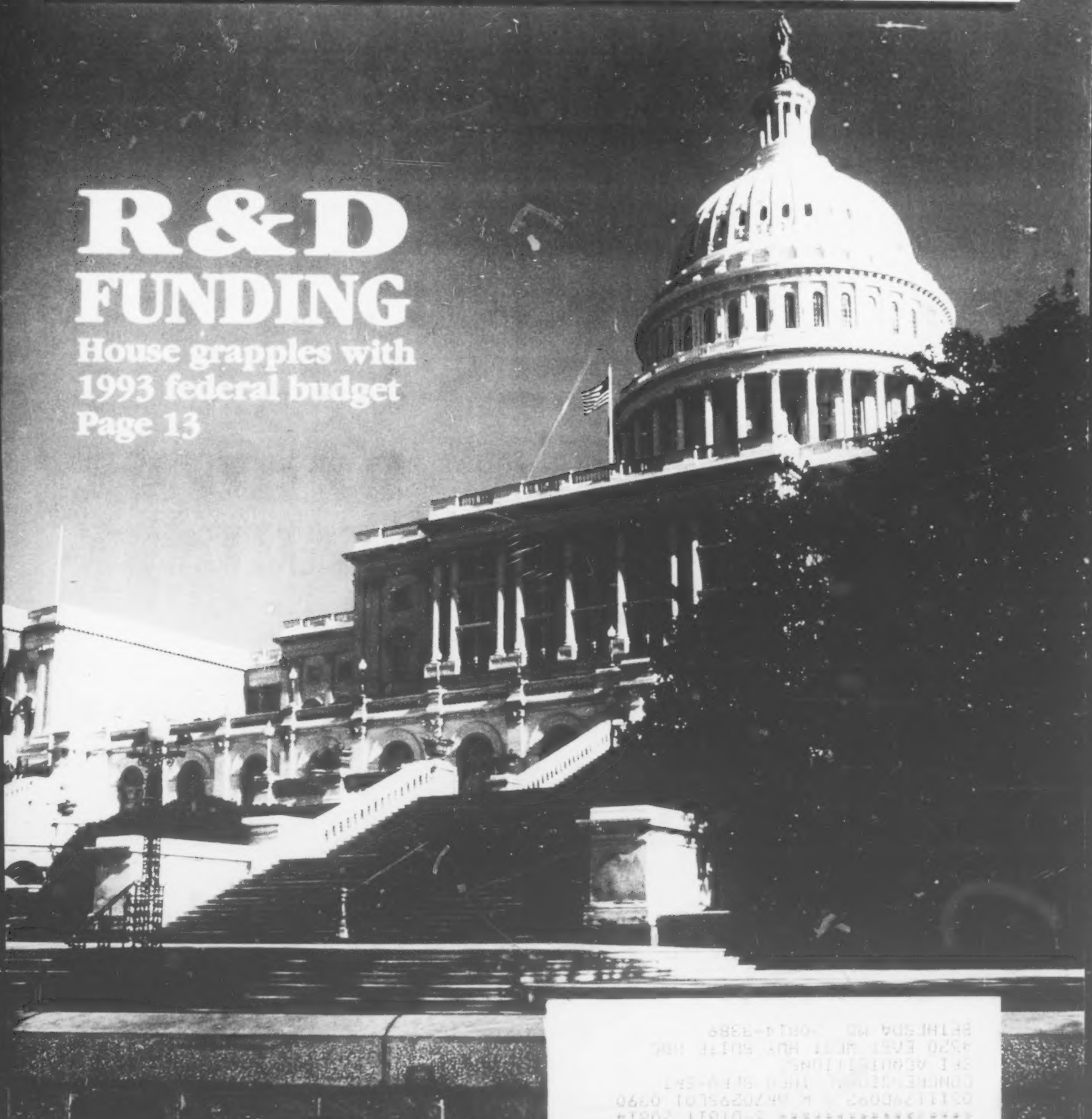
RESEARCHERS MAKE NANOCOMPOSITE THAT IS MAGNETIC, TRANSPARENT PAGE 20



R&D FUNDING

House grapples with 1993 federal budget
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C&EN
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NEWS OF THE WEEK

- Simple way to make bulk quantities of microscopic tubular carbon structures, called "carbon nanotubes," has been developed by Japanese researchers. **Page 4**
- No criminal charges will be filed in the alleged falsifying of lab work by Thereza Imanishi-Kari to support a paper she coauthored with Nobelist David Baltimore and others in 1986. **Page 5**
- Astronauts have completed 14-day microgravity lab mission, successfully performing dozens of scientific experiments under low gravity. **Page 5**
- Hostile business climate has pushed New Jersey's chemical industry into decline, requires changes in state policy, industry council study finds. **Page 6**

COVER: Photo by Alan Kahan

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BUSINESS

Rules of origin are currently being scrutinized closely in North American free trade talks, with industry supporting simplified rules and emphasis on tariff shifts. **Page 9**

Dow has repackaged its hydrocarbons group into a wholly owned subsidiary to better service the company's petrochemicals business in the U.S. **Page 10**

GOVERNMENT

U.S.-Japan global partnership plan, signed during President Bush's January trip to Japan, is receiving belated interest by State Department officials. **Page 16**

EPA is revamping its massive and mismanaged contract program, changing the agency's internal operation and relationships with private firms. **Page 18**

SCIENCE/TECHNOLOGY

Material that is magnetic at room temperature and optically transparent has potential applications in color imaging, refrigeration, and computer memory. **Page 20**

Process for polymerization of aspartic acid may lead to use of these biodegradable resins instead of polyacrylic acid in certain applications. **Page 21**

DOE's clean-coal technology demonstration program is entering its final proposal stage, with emphasis on superclean, high-efficiency, coal-based systems. **Page 21**

Research on embedding chemical compounds in porous glass has reached the point of commercialization with potential licensees being sought. **Page 22**

COVER STORY

House budget writers tighten 1993 R&D funds for "big" and "little" science programs—and eliminate all Superconducting Super Collider funds—in response to severe budget restraints. Page 13

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
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LETTERS

Science and society

In his review of Brian Martin's survey of the fluoridation controversy (C&EN, June 29, page 76), Patrick W. Hamlett contrasts the "social constructivist" approach with what he believes to be the traditional approach to scientific progress. He grossly misrepresents the traditional approach and perpetuates a serious error.

According to Hamlett, "Empirical data cannot fully explain why one scientific theory is accepted and others are rejected." An attempt to explain why one scientific theory is accepted or not is itself a theory, and must therefore seek to explain its own acceptance or rejection. In this process, empirical data cannot explain any phenomenon, fully or otherwise. Empirical data are simply anecdotal—they can weigh against a theory, but can never serve to prove a theory—and under no circumstances can they explain a theory.

Hamlett also states that "the scientists' claims to truth should not receive a privileged place." No scientist worthy of the term lays any claim to truth, and a scientist who does claim to have discovered the truth will on that basis alone be regarded suspiciously by genuine scientists, to say nothing of not receiving a privileged place.

In the fluoridation controversy, as with many other scientific issues with broad social (and therefore political) implications, the reasons why some scientists might tentatively accept a theory can be significantly different from the reasons why politicians and citizens accept the social implications of that theory. (This even allows a scientist to view the issue differently in his or her capacity as a scientist and as a citizen.) Much of the heat in this particular issue, for example, was over the political and sociological merits of imposing the scientific implications on the populace by force. Social engineers who pressed for fluoridation clearly never considered that they might be violating a fundamental principle of a free society, because they thought they were acting unselfishly according to delivered scientific truth. Forget that they might have been scientifically wrong (a suggestion that Hamlett clearly weighs more than his critic, Edward Groth); the social constructivist approach merely recognizes that the criticism should not end just because scientific consensus has been reached.

In the fluoridation controversy, the weight of scientific evidence in support of a particular theory was wielded as a club by social engineers who pressed their agenda. Anyone who opposed them on a political or moral basis was therefore a barbarian, or worse, out to increase the misery of the populace. With that opposition, is it any wonder that opponents of fluoridation sought scientific basis for their arguments? This is what Hamlett appears to have documented more fully than his predecessors.

The same perspective on other debates—including, but not limited to, the use of automobile safety belts and motorcycle helmets—might shed some light. It is fundamentally wrong politically, morally, and perhaps even scientifically to force people to do what scientists believe is good for them. Certainly the scientific debate should never be terminated, but even when there appears to be overwhelming evidence in support, the debate over whether or not to force the implications on society will continue to be legitimate.

Dan Karlan
Waldwick, N.J.

Robert Parry

The American Chemical Society should be highly commended for its selection of Robert W. Parry for the Priestley Medal (C&EN, May 25, page 21). He also deserves the title of ideal citizen of the world. I believe that Bob Parry's unique modesty, integrity, unselfishness, morality, and humor had, until the Priestley Award, often allowed colleagues to overlook the fact that he is a great chemist and teacher. He never trumpeted his contributions.

In illustration of his unselfishness, before Bob left Michigan to return to his roots, he took a slender passageway as his office because of a crowded department. In illustration of his tolerance, he insisted that I play not one, but several selections on my harmonica.

Joseph H. Burckhalter
Research Professor
Florida Institute of Technology
Melbourne, Fla.

Correction

- May 18, page 38: In the list of 50-year members of ACS, Robert B. Fischer was incorrectly listed as Robert Richard Fischer.

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House Cuts Wide Swath in 1993 Funds For Federal R&D Projects

■ ***"Big" and "little" science programs get squeezed as budget writers adhere to severe spending restraints***

Janice R. Long, C&EN Washington

While the attention of much of the scientific community was focused on the House's vote to deny fiscal 1993 funding, by a surprisingly wide margin, for one of the so-called big science projects—the Superconducting Super Collider—the budget requests for numerous "little science" programs were also being cut back, sometimes to below current spending levels.

And it's unlikely that money saved by cutting the SSC or any of the other big science projects will find its way into the pockets of little science. This year it's not a question of funding big science or little science, but big science or no science. Although the Senate has yet to act on any of the fiscal 1993 money bills, its Appropriations Committee is working with the same, very limited amount of money that the House counterpart had to dole out in fashioning next year's federal budget.

A longtime follower of trends in federal science funding sees this year as the dawning of an era of very modest increases or perhaps even level funding for federal science programs that had become accustomed to fairly substantial increases—ranging from 15 to 17% in some cases—during the past several years.

That's because fiscal 1993 is the year in which the highly publicized 1990 budget agreement, which divided federal spending into three separate categories, each with its own spending cap, "is coming home to roost," says Rep. George E. Brown Jr. (D.-Calif.), chairman of the House Committee on Science, Space & Technology. "My own hope, at least in the areas where there is the greatest danger—the big sciences—is just to survive this year and try to improve the situation next year." Brown's committee oversees the operations of the National Science Foundation and the National Aeronautics & Space Administration, as well as the research programs of the Department of Energy and the Environmental Protection Agency.

"The climate for any kind of funding is not very good" this year, he says. "Is it worse for science funding than it is for others? The answer to that is mixed," he adds. "I think for the large science projects it's going to be worse. Because they are a bigger target, they are going to be in serious trouble."

Funding for the SSC was not robust even before the House vote. The Administration had requested a 35% funding increase for the SSC to $650 million, but the Appropriations Committee, citing "severe budget restraints," froze its funding at the current level of about $484 million, even though it said it "strongly supports the construction of the SSC."

C&EN staff photo

Brown: spending caps coming home to roost

If the committee had hoped to forestall further cuts, it was unsuccessful (C&EN, June 22, page 5). The timing of the SSC vote was bad, coming as it did a week after the defeat of a Constitutional amendment that would have required a balanced federal budget. It was an obvious $8 billion target whose costs, opponents argued, were out of control and were robbing not only taxpayers but also important laboratories around the country of funds. And the Texas Congressional delegation was in the uncomfortable position of leading the fight for the SSC, after having been a force behind the balanced budget amendment. Under the House amendment, any savings from terminating the SSC will simply be taken out of DOE's budget, perhaps reducing the deficit. It will not be used to increase funds for other energy research programs.

Brown, for one, is "very unhappy with the way in which the decision to terminate the SSC was made. It was an emotional vote rather than a rational vote. ... There were votes being cast to get even with people—Californians trying to get even with Texans, and Texans trying to get even with Californians. It was not a good way to legislate."

There may be more than a grain of truth there. Budget cutters weren't able to muster enough votes to cut just $700 million from the fiscal 1993 funding for the biggest big science project of all—the Strategic Defense Initiative, which has cost $29 billion to date and was the next big science project to come to the House floor. But they came close, with a vote of 217 against and 201 in favor. As approved by the House, funding for SDI would be up $1.1 billion, or 27% over current spending, to $4.2 billion. However, the Administration had asked for a 60% increase to $5.3 billion. If the amendment had passed, sponsors said the $700 million would also have been used to reduce the deficit.

The next test for big science will involve funding for space station *Freedom*. The Appropriations Subcommittee on VA, HUD & Independent Agencies has recommended that NASA's overall budget be set at $13.9 billion, which is several hundred million dollars below the current level of funding and about $1 billion below the President's request, Brown says. The subcommittee has also recommended $1.75 billion for the space station, "which is way below [both] the current level of funding and the President's request." The full Appropriations Committee is expected to take the Veterans Affairs, Housing & Urban Development, and Independent Agencies bill up this week, with a vote by the full House probably coming during the week of July 27.

Space station supporters will most likely argue that the subcommittee's recommended cut of 12% in station funding, if it is approved by the full Appropriations Committee, is more than enough to show fiscal responsibility. However, Brown says, "it is my expectation that an amendment will be offered on the House floor to cut [the space station] completely, except for termination costs." But he adds, "We expect to defeat that amendment."

All the attention focused on big science has somewhat obscured the fact that little science isn't faring very well either. Brown says, "The normal science programs, and that includes all of the National Institutes of Health and all of NSF, are going to suffer some cuts, but they are going to continue to grow; it's just that the rate of growth won't be as rapid." For DOE, he expects it "to end up with zero growth or small cuts in their other science budgets. So, it's just not a good year."

That certainly is holding true of funding for DOE's other science programs in fiscal 1993, though the road to level funding can be tricky. For example, the Appropriations Committee at first agreed with the Administration's request for a 6% increase to $814 million in funding for DOE's basic energy sciences program. That included an increase of 11% to $175 million for chemical sciences and of 13% to $290 million for materials sciences. But then the committee, citing "severe budget constraints," imposed a general reduction of $49 million, which brought the program's funding back down to its current level of $765 million and left programs such as chemical sciences, whose funding was frozen at last year's level this year, looking at another bleak budget year.

Funding for nuclear R&D would be down 10% to $304 million, and that for biological and environmental research and magnetic fusion research would increase just 1%. The only bright spots in the DOE R&D budget so far are those areas related to cleaning up contamination at DOE facilities, which would be up 18% to $710 million, and energy conservation, up 20% to $311 million. That funding for energy conservation might change, however, since it has not yet come up for a floor vote in the House.

Overall funding for the Department of Defense's R&D programs would be unchanged from this year's $38.5 billion, under its House-passed appropriations bill. The Navy's research funding, however, would increase, up 9% to $9.3 billion. Army research would be cut 12% to $5.8 billion, Air Force research would be cut 3% to $13.7 billion, and research by the defense agencies would be down 5% to $9.5 billion. The House bill would direct DOD to invest $180 million in advanced materials research; $20 million in the computer consortium, Sematech; and $330 million in manufacturing technology development in 1993. The manufacturing technology program would fund such things as the National Center for Excellence in Manufacturing Technology, advanced gear manufacturing, and the design and manufacturing of high-performance composites. The bill also would provide full funding, $176 million, for the national aerospace plane.

The only other research-related appropriation bill approved by the House before it recessed for the Democratic National Convention was that providing funding for the U.S. Department of Agriculture. Overall USDA research funding would be down 5% to $1.3 billion under the bill, with the Cooperative State Research Service taking the hardest hit, down 12% to $446 million, which is still 7% more than the Administration requested. However, the Appropriations Committee did not provide the 54% increase to $150 million requested for the National Research Initiative, which supports the only research grants at USDA distributed under a competitive peer review system. Instead, it froze funding for the initiative at the current level of $97.5 million.

It also ignored the Administration's request for a funding cut of 60% in the special research grants program—which was prominent on President Bush's list of pork-barrel projects that he wanted cut from the federal budget earlier this year (C&EN, May 25, page 14). Although defending the program as applied development that didn't need to be peer reviewed or awarded on a competitive basis, the committee did cut it back 21% from current spending levels to $57.7 million and cut the number of projects supported under the program from 141 to 85.

That didn't satisfy members of the House's self-styled "Porkbusters Coalition" who backed a floor amendment to cut all funding for special research grants. Coalition cochairman Harris Fawell (R.-Ill.) said the program represented the "purest form of pork-barrel spending, not because of the subject matter of the 85 spending projects but because it completely bypasses established procedures and criteria for spending." Fawell admitted there wasn't really that much money at stake but maintained, "if we are unable—or unwilling—to cut funding for 85 projects that have basically bypassed the appropriations process, then I doubt very much we will make hard choices necessary to even significantly cut the projected $400 billion deficit for fiscal 1993," let alone bring the federal deficit under control without the Constitutional mandate rejected three weeks ago. However, after a spirited debate that actually consumed more than twice as much space in the *Congressional Record* as the debate concerning cutting SDI funding $750 million, Fawell's amendment was also defeated.

NSF's fiscal 1993 budget, which advances in tandem with NASA's, is scheduled for full committee markup this week. The American Chemical Society last week sent a letter to Appropriations Committee chairman Jamie L. Whitten (D.-Miss.), and, for good measure, to 434 other House members, ex-

House actions bode ill for 1993 research funding

$ Millions	1993 House appropriation	 Administration request	1992	% difference Appropriation-requested	% change 1992–93
DOD R&D	$38,520.5	$38,626.4	$38,765.9	0%	–1%
Tactical programs	13,773.1	13,241.1	14,742.7	4	–7
Intelligence & communications	4,629.1	5,011.2	5,201.4	–8	–11
Technology base	4,608.9	4,083.9	4,184.8	13	10
Strategic programs	4,366.5	4,507.1	4,278.7	–3	2
Defensewide mission support	4,360.0	3,960.8	3,846.8	10	13
Strategic Defense Initiative	4,237.5	5,312.4	3,321.3	–20	27
Advanced technology development	2,545.4	2,509.9	3,090.2	1	–18
NASA R&D[a]	6,679.7	7,687.4	7,004.7	–13	–5
Space station[b]	1,750.0	2,238.9	1,986.8	–22	–12
Energy	5,271.4	6,580.1	6,309.1	–29	–16
Energy R&D	4,469.8	5,165.9	4,876.5	–13	–8
General science & research	965.2	1,652.7	1,472.5	-42	–35
Superconducting Super Collider[b]	0	650.0	483.7	–100	–100
Basic energy sciences	764.7	813.9	764.7	–6	0
Environmental restoration & waste management	709.7	707.0	602.5	0	18
Fossil fuels[c]	412.6	311.3	452.3	32	–8
Biological, environmental	356.7	384.7	353.3	–7	1
Fusion	339.7	359.7	337.1	–6	1
Nuclear	304.3	310.3	336.7	–2	–10
Conservation[c]	311.4	326.1	260.1	–5	20
Solar, other renewables	249.8	245.9	242.8	2	3
University & science education programs	55.7	55.7	54.5	0	2
Weapons R&D	1,431.6	1,414.2	1,432.6	1	0
NSF[a]	2,541.0	2,888.0	2,465.8	–12	3
Research & related activities	1,879.0	2,211.5	1,879.8	–15	0
Education & human resources	465.0	479.5	465.0	–3	0
Antarctic program	163.0	163.0	88.0	0	85
Instrumentation & facilities	33.0	33.0	33.0	0	0
Critical Technologies Institute	1.0	1.0	0	0	100
USDA	1,327.1	1,300.4	1,396.7	2	–5
Agricultural Research Service	694.4	714.0	711.5	–3	–2
Cooperative State Research Service	446.0	416.3	504.7	7	–12
Forest research[c]	186.7	170.1	180.5	10	3
EPA extramural R&D[a]	338.5	341.0	323.0	–1	5
TOTAL	$54,678.2	$57,423.7	$56,265.2	–5%	–3%

Note: All numbers are estimates. **a** Amounts recommended at appropriations subcommittee level. **b** Funds included in total. **c** Amount approved by the Appropriations Committee.

pressing its concern that "if domestic discretionary budget cuts become necessary during the fiscal 1993 appropriations process, continued funding for space station *Freedom* may weaken support for scientific programs, particularly those within NSF and EPA." ACS recommends that, if such cuts do become necessary, the space station program be postponed in favor of other basic scientific research priorities in the bill, which "will enable the U.S. to meet today's economic challenges and to prepare for those of tomorrow."

At press time it was too early to tell if ACS's recommendation would be heeded. The VA subcommittee has recommended that funds for NSF's research and related activities account be frozen at the current level of $1.9 billion, and that the reductions from the $2.2 billion budget request be spread proportionately across all scientific disciplines. It also recommends that funds for research facilities and instrumentation be frozen at $33 million and that those for education and human resources remain at $465 million. The Appropriations Committee, to date, has been accepting the majority of its subcommittees' funding recommendations.

There is no guarantee, however, that if space station funding is canceled, that that money would be used to increase funding for NSF and/or EPA. As Brown recently reminded his colleagues after the SSC vote: "Any money that is saved by terminating the SSC will not necessarily flow to other scientific projects, regardless of whether they are high or low priority. In fact, despite rhetoric to the contrary, terminating the SSC may not even lead to deficit reduction. Because of the nature of the appropriations process, it is just as likely that any SSC savings will be expended on nonscientific programs such as water development." Money saved by delaying or terminating the space station is just as likely to go for veterans health programs or to support housing for the poor.

Brown also pointed out that "big science projects are not big because of pork-barrel considerations. They are large because shared, complex facilities have become essential to scientific progress in a whole range of disciplines, including astronomy, oceanography, computing, and biology, as well as physics." And he warned: "If we expect to continue to be world leaders, we cannot expect to revolutionize science by watching apples fall from a tree. We will need an appropriate balance of small and big science. It is mindless to oppose all big science projects, simply because they are big. In doing so, we virtually guarantee that many fundamental breakthroughs in our understanding of nature will not occur in the U.S." ☐

Third Set of 1992 PRF Grants Approved

Acting on recommendations from the May meeting of the Petroleum Research Fund Advisory Board, the ACS Board of Directors approved 164 new or continuing ACS-PRF grants-in-aid. Forty-one of the grants include a supplement of $3000 to involve an undergraduate student in the research. May commitments total $5,036,160. The recommended grants were selected from 460 proposals and are the last projects to be funded in 1992. Total ACS-PRF grant commitments in 1992 are $14,413,529. ACS-PRF grants are funded by income from a trust established in 1944 by seven major oil companies. No ACS member dues income is used for PRF grants or administrative expenses.

The maximum values for ACS-PRF grants in 1993 have been increased: Type AC, $25,000 per year for up to three years; Type B, $25,000 over two years; and Type G (starter), $20,000 over two years. Applicants should note the revised limits for the scientific text of 4000 words for PRF Type AC and B proposals, and 1700 words for Type G proposals. For 1993 grants, the maximum salary and benefits that the principal investigator may receive each year will be $5000, and the annual limit for travel will be $1000. Applicants from Ph.D.-granting departments may request a $3000 supplement to fund an undergraduate research student.

Proposals for projects to commence in 1993 are invited for all ACS-PRF research grant programs. Information and application forms may be obtained from the Petroleum Research Fund, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036, or by calling (202) 872-4481.

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type AC)

Richard W. Allmendinger, Cornell U. The Importance of Small Faults in Compressional and Extensional Deformation. $40,000

Robert S. Anderson, U of California, Santa Cruz. Response of Badlands to Base Level Forcing: Examples from the Fremont River on the Colorado Plateau. $43,000

Paul F. Barbara, U of Minnesota. Definitive Vibrational Spectroscopy of the Solvent-Coordinate/Solvation Sphere. $40,000

Peter F. Bernath, U of Arizona. Laser and Fourier-Transform Spectroscopy of Free Radicals. $40,000

Robert A. Bernheim, Pennsylvania State U. Effects of Optical Orientation on Chemical Equilibria. $40,000

Norman O. Birge, Michigan State U. Nonlinear Susceptibilities and the Glass Transition. $40,000

Donna G. Blackmond, U of Pittsburgh. Spectroscopic Studies of Adsorption and Reaction over Supported Ru Catalysts for Selective Hydrogenation Reactions. $43,000

John R. Bleeke, Washington U. Synthesis and Reactivity of Metallacyclohexadiene and Metallabenzene Complexes. $40,000

R. Mark Bradley, Colorado State U. The Effect of Grain Asphericity on the Properties of Sandstones. $40,000

David A. Budd, U of Colorado. A Chemostratigraphic Analysis of a Paleozoic Upwelling Zone in the Permian Phosphoria Sea, West-Central Wyoming and Eastern Idaho. $40,000

Drury S. Caine, U of Alabama. The Synthesis of 7-Heterosubstituted Bicyclo [2.2.1] Heptanones via Anion-Assisted Diels-Alder Reactions. $43,000

John P. Caradonna, Yale U. Reactivity Models for Nonheme Iron Metalloenzymes. $43,000

Louis A. Carpino, U of Massachusetts. A Superior Peptide Coupling Additive. $43,000

Kenneth G. Caulton, Indiana U. π-Donor-Stabilized Unsaturation: Principles and Applications. $43,000

S. H. Chan, U of Wisconsin, Milwaukee. Solubility and Polymerization of Silica in Hydrothermal Fluids. $40,000

David S. Chapman, U of Utah. Thermal History of the Taranaki Sedimentary Basin, New Zealand. $43,000

Nicholas Christie-Blick, Columbia U. Late Devonian Sequence Stratigraphy of the Canning Basin, Australia: Implications for Eustasy and Applications in Petroleum Exploration. $40,000

Milton W. Cole, Pennsylvania State U. Physical Adsorption on Weak Binding Surfaces. $40,000

Philip Coppens, State U of New York, Buffalo. The Response of Transition-Metal Compounds to External Perturbations. $40,000

Joyce Y. Corey, U of Missouri, St. Louis. Catalyzed Dehydrocoupling of Silanes: Routes to Catenated Silicon Compounds. $40,000

Stephen P. Cramer, U of California, Davis. High-Resolution Time-Resolved X-Ray Fluorescence: Application to Photosynthetic Manganese. $40,000

Robert C. Dunbar, Case Western Reserve U. Low-Temperature Ion Chemistry in a Cooled FT-ICR Ion Trap. $60,000

Mark D. Ediger, U of Wisconsin, Madison. Molecular Investigation of Physical Aging in Polystyrene. $43,000

Eric D. Edstrom, Utah State U. Conformational and Stereochemical Factors in the Synthesis of Medium-Ring Lactams. $40,000

Derek Elsworth, Pennsylvania State U. Real-Time Hydraulic Fracture Characterization from Adjacent Well Data. $40,000

James P. Evans, Utah State U. Field and Microstructural Analyses of Deformation in Footwalls of Thrust Faults: Significance for Geometry, Kinematics, and Mechanics of Thrust Fault Evolution. $37,800

James M. Farrar, U of Rochester. Mass-Selected Solvated Cluster Ions: Size-Dependent Photochemistry. $60,000

Richard G. Finke, U of Oregon. Synthesis and Characterization of Polyoxoanion-Ruthenium Oxygenation Catalysts: Oxidation-Resistant Inorganic Porphyrin Analogs. $43,000

David A. Forsyth, Northeastern U. NMR Isotope Shifts as a Probe of Organic Structure. $40,000

Raymond P. Freeman-Lynde, U of Georgia. Geochemical Investigation of Equant Calcite Spars in Limestones from DSDP Sites 390 and 392, Blake Nose: Implications for Deep-Marine Diagenesis of Shallow-Marine Carbonate Platforms. $40,000

Michael D. Fryzuk, U of British Columbia. New Lewis Acid-Lewis Base Interactions. $40,000

John F. Garst, U of Georgia. Radical Exchange in Grignard Reagent Formation. $40,000

Dana H. Geary, U of Wisconsin, Madison. Foraminiferal Stable Isotopes and the Miocene-Recent Environments of the Eastern Equatorial Pacific and Southwestern Caribbean. $40,000

John L. Gland, U of Michigan. Surface Reduction of Hydrocarbons and Alcohols by Hydrazine on Platinum, Rhodium, and Iridium Surfaces. $40,000

Richard D. Gonzalez, Tulane U. The Preparation of Silica-Supported High-Surface-Area Metal Catalysts by the Sol-Gel Method. $40,000

Ronald L. Halterman, U of Oklahoma. Synthesis and Applications of Chiral Bridged Metallocenes. $40,000

Mark J. Hampden-Smith, U of New Mexico. Molecular Routes to Complex Metal Oxides with Controlled Stoichiometry. $40,000

Thomas J. Hanratty, U of Illinois, Urbana-Champaign. Polymer Drag-Reduction. $43,000

W. Dean Harman, U of Virginia. Dihepto-Coordinated Phenols as Organic Synthons. $43,000

Harold C. Helgeson, U of California, Berkeley. Chemical Interaction of Minerals and Hydrocarbons with Aqueous Solutions in Sedimentary Basins. $40,000

James W. Herndon, U of Maryland, College Park. Homo-Michael Addition Reactions Using Cyclopropylcarbene Complexes. $40,000

Jonathan J. L. Higdon, U of Illinois, Urbana-Champaign. Dynamics of Concentrated Polydisperse Suspensions. $40,000

David A. Hodell, U of Florida. Global Correlation of Oligocene-Miocene Strata Using Strontium Isotope Stratigraphy. $40,000

David W. Houseknecht, U of Missouri, Columbia. Inorganic and Organic Thermal Maturity Indexes in Shales. $40,000

Andreas J. Illies, Auburn U. Gas-Phase Two-Center Three-Electron Bonding in Organic Molecules and Ion-Molecule Clustering Involving H_3O^+, H_2O^+, NH_4^+ and NH_3^+. $40,000

Paul W. Jewell, U of Utah. Coastal Circulation Models and the Prediction of Geochemical Facies in Upwelling Zones. $43,000

Mercouri G. Kanatzidis, Michigan State U. Chemistry of Soluble Metal Polychalcogenides. $40,000

Steven R. Kass, U of Minnesota. Vinyl and Cyclopropyl Anions: Formation, Reactivity, Structural Stability, and Thermodynamic Properties. $43,000

Hilkka I. Kenttamaa, Purdue U. Ion-Molecule Reactions of Distonic Radical Cations in the Gas Phase. $40,000

Sangtae Kim, U of Wisconsin, Madison. Microhydrodynamics of Complex Aggregates. $40,000

Bernard Kirtman, U of California, Santa Barbara. Accurate Calculation of Electron Correlation, Nonresonant Frequency Dispersion, and Vibrational Distortion Effects on Nonlinear Optical Properties of Conjugated Polymers. $40,000

Satyendra Kumar, Alfred Saupe, Kent State U. Precision Heat Capacity and High-Resolution X-Ray Diffraction Study of Phase Transitions in Surfactant Solutions. $43,000

Harold H. Kung, Northwestern U. Role of Metal-Oxygen Bond Strength and Reduced Cations in Selective Oxidation of Hydrocarbons. $43,000

Paul M. Lahti, U of Massachusetts. Dinitrene Models of Exchange Coupling: Investigations of Organic Ferromagnetism. $40,000

Stephen Lee, U of Michigan. Second Moment Scaling and Covalent Crystal Structure. $40,000

David B. Loope, U of Nebraska, Lincoln. Eolian Reworking and Meteoric Diagenesis at a Subtle Jurassic Unconformity, Central Wyoming. $40,000

Przemyslaw B. Maslak, Pennsylvania State U. Magnetic Interactions in Perfluorinated Radicals. $43,000

Lon J. Mathias, U of Southern Mississippi. Adamantane-Based Dendrimers and Pseudo-Buckyballs: Synthetic Approach to Molecules-in-a-Box. $43,000

Krzysztof Matyjaszewski, Carnegie Mellon U. Living Cationic Polymerization of Alkenes: Exchange Processes. $40,000

Lisa McElwee-White, Stanford U. Photooxidative Cyclizations of Metal Carbynes. $43,000

Philip A. Meyers, U of Michigan. Early Diagenesis of Lacustrine Organic Matter. $43,000

Gary A. Molander, U of Colorado. Organolanthanides as Catalysts in Selective Organic Synthesis. $40,000

Philip C. Nelson, U of Pennsylvania. Shape Changes in Surfactant Bilayers and Interfaces. $40,000

Peter Nordlander, Rice U. Nonadiabatic Effects in Atom-Surface Scattering. $40,000

John P. Oliver, Wayne State U. Synthesis, NMR, and Structural Studies on Organoaluminum Compounds. $40,000

Catherine J. Page, U of Oregon. Self-Assembled Multilayer Structures Based on Novel Inorganic-Organic Layered Compounds. $40,000

Vernon D. Parker, Utah State U. Thermochemistry of S_N1 Ionization Reactions of Alkyl Halides. $40,000

George A. Parks, Stanford U. Direct Observation of Hematite Dissolution by Organic Acid. $40,000

Laura A. Philips, Cornell U. The Role of Vibrational Mode-Coupling in Chemical Reactions. $40,000

Donald J. Plazek, U of Pittsburgh. The Recoverable Creep Compliance of Glass-Forming Materials. $40,000

Richard P. Polniaszek, Duke U. Preparation and Synthetic Utility of Phosphorus Heterocycles. $43,000

Kevin T. Potts, Rensselaer Polytechnic Inst. 1,4-Dipolar Cycloaddition Route to Aspidosperma Alkaloids. $40,000

Philip P. Power, U of California, Davis. Synthesis and Reactivity of Compounds with Multiple Bonding between Main Group 3 Elements. $40,000

Thomas R. Rizzo, U of Rochester. New Spectroscopic Probes of Intramolecular Dynamics. $40,000

James P. Runt, Pennsylvania State U. Quantitative Fractographic Analysis of Polymers. $43,000

Dilano K. Saldin, U of Wisconsin, Milwaukee. Chemically Specific Local Crystallography by X-Ray Absorption, Photoemission, and Holography. $40,000

Charles P. Scholes, State U of New York, Albany. Application and Technical Development of Stopped-Flow EPR. $40,000

Gary J. Schrobilgen, McMaster U. New Synthetic Initiatives in the Chemistry of Highly Electronegative Fluorinated Ligands. $40,000

Don Secrest, U of Illinois, Urbana-Champaign. Angular Momentum in Molecular Collisions. $43,000

Kevin L. Shelton, U of Missouri, Columbia. Diagenesis of Cambrian and Ordovician Platform and Basinal Carbonates by Basinal Fluids: Petrologic and Geochemical Studies in the Reelfoot Graben, Southeastern Missouri. $40,000

Steven J. Sibener, U of Chicago. Molecular Beam Studies of Surface Chemical Kinetics. $63,000

J. Antonio Simo, U of Wisconsin, Madison. Porosity Preservation in Waulsortian Buildups, Lower Carboniferous Pekisko, West-Central Alberta. $33,560

Johannes Smid, State U of New York, C of Environmental Science & Forestry. Novel Amphiphilic Hydrogels with Immobilized Cation-Chelating Ligands. $40,000

Paul E. Sokol, Pennsylvania State U. Structure and Dynamics of Adsorbed Systems in Porous Media. $43,000

Kenneth S. Suslick, U of Illinois, Urbana-Champaign. Porphyrin Assemblies. $40,000

Philip L. Taylor, Case Western Reserve U. Theory of Phase Separation in a Polymerizing Mixture. $40,000

Gregory R. J. Thatcher, Queen's U. Hydrophobic Catalysis and Transition-State Structure. $40,000

Michael A. Walters, Dartmouth C. General Investigations of a Mild and Efficient 3-Aza-Claisen Rearrangement. $40,000

Peter T. Wolczanski, Cornell U. C–N Bond Cleavage Reactions Relevant to Hydrodenitrogenation. $40,000

Ralph T. Yang, State U of New York, Buffalo. Simultaneous Purification and Sorbate Recovery by New Pressure-Swing Adsorption Cycles. $40,000

Danny L. Yeager, Texas A&M U. Developments with Multiconfigurational Linear Response for Electronic Excitation Energies and Response Properties. $40,000

Tadeusz W. Zerda, Texas Christian U. Molecular Motion of Small Molecules in Porous Sol-Gel Glass. $43,000

William J. le Noble, State U of New York, Stony Brook. Measurement and Control of Face Selection in Heteroadamantanones. $40,000

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type B)

Edward R. Biehl, Southern Methodist U. Investigation of the Synthetic Utility of the Tandem Addition-Rearrangement and Aryne Arylation Reactions for the Elaboration and Annulation of Certain Fused Aromatics. $20,000

Andrew P. Craft, Lafayette C. Phase Diagrams for Hydrogen in Alloys of the Group 5B Metals via Differential Scanning Calorimetry. $19,600

Franklin P. DeHaan, Occidental C. Scope, Kinetics, and Mechanism of Double-Agent Halogenation. $20,000

Gregory W. Ebert, State U of New York, Buffalo. The Direct Formation of Haloaryl and Halovinyl Copper Reagents via Activated Copper. $20,000

Richard H. Fluegeman, Ball State U. Late Eocene Benthic Foraminiferal Paleoecology of the Mossy Grove Cove, Hinds County, Mississippi. $17,500

Raymond J. Giguere, Skidmore C. Novel Intramolecular Ene Reactions. $20,000

Gary H. Girty, San Diego State U. A Comprehensive Sedimentological Model for Chert-Argillite Units in the Lower Paleozoic Shoo Fly Complex. $20,000

Karen I. Goldberg, Illinois State U. Reactivity Trends in Reductive Elimination Reactions. $20,000

Martin R. Hulce, Creighton U. Nucleophilic 1,8 Additions to Mixed-Hybridization-State, Conjugated Ketones: Neocarzinostatin Chromophore Models. $20,000

Frederick W. King, U of Wisconsin, Eau Claire. On the Question of the Stability of the Halide Ion. $20,000

Dennis W. Lindle, U of Nevada, Las Vegas. Ionization and Fragmentation Dynamics of Gases Using Hard X-Ray Synchrotron Radiation. $20,000

John A. Maguire, Southern Methodist U. Theoretical Studies of Main-Group π-Complexes. $20,000

Mark D. Marshall, Amherst C. Diode Laser Spectroscopy of Ammonia-Containing van der Waals Complexes: Models for Hydrogen Bonding. $20,000

Ronald L. Musselman, Franklin & Marshall C. Polarized Specular Reflectance of Metalloprotein Models and One-Dimensional Conductors. $20,000

Charles G. Oviatt, Kansas State U. Lake Bonneville Marl Stratigraphy and Lake Fluctuations. $20,000

Robert S. Paley, Swarthmore C. Asymmetric Cycloadditions of Enantiopure Unsaturated Sulfoxides and Sulfoximines. $20,000

Brady P. Rhodes, California State U, Fullerton. Investigation of a Metamorphic Core Complex in Northern Thailand: A Study of the Doi Suthep Mylonites, Chiang Mai District. $20,000

Herbert B. Silber, San Jose State U. Metal Ion Complexation Reactions. $20,000

Jinke Tang, Ashok Puri, U of New Orleans. Study of Room-Temperature Magneto-Optical Recording Materials. $20,000

John F. Taylor, Indiana U of Pennsylvania. Biostratigraphy of Late Cambrian and Early Ordovician Carbonates in the Central Appalachians. $20,000

Gerald R. Van Hecke, Harvey Mudd C. Thermodynamic Excess Functions Measured by Laser Light Scattering. $20,000

Patty Wisian-Neilson, Southern Methodist U. New Sulfur-Containing Phosphazenes. $20,000

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type G)

Michael T. Ashby, U of Oklahoma. Lamellar Solid-State Organization with Amphiphilic Metal-Organic Compounds. $21,000

Nitash P. Balsara, Polytechnic U. Complex Polymer Fluids. $18,000

Scott W. Barton, U of Massachusetts. Structure in the Ion-Conducting Phase of Polymer Electrolytes: A Differential Anomalous X-Ray Scattering Study. $18,000

John G. Brennan, Rutgers U. Organosoluble Metal Oxide Nanoclusters. $21,000

Vince Cammarata, Auburn U. Synthesis, Spectroscopy, and Electrochemistry of Aromatic and Inorganic Langmuir-Blodgett Films. $18,000

Joseph I. Cline, U of Nevada, Reno. Laser Spectroscopic Studies of Reaction Mechanism and Dynamics in Large Molecules. $21,000

Peter K. Dorhout, Colorado State U. Synthesis and Characterization of Novel Materials of Ternary Noble-Metal Chalcogenides. $18,000

Erik J. Fernandez, U of Virginia. Magnetic Resonance Imaging Analysis of Miscible Viscous Fingering in Porous Media. $21,000

Katherine H. Freeman, Pennsylvania State U. Molecular and Isotopic Biogeochemistry of Sinking Particles in the Black Sea. $18,000

Miguel A. Garcia-Garibay, U of California, Los Angeles. The Norrish Type-II Reaction of Ditopic Aromatic Ketones: An Entry to Chemical Dynamics and Structure-Reactivity Correlations in Solid-State Organic Chemistry. $21,000

John H. Griffin, Stanford U. Semisynthetic Vancomycin Derivatives with Catalytic Activity. $21,000

John M. Jean, Washington U. Ground-State and Transient Resonance Raman Scattering from Strongly Coupled Porphyrin Macrocycles. $21,000

Leslie S. Jimenez, Rutgers U. Photo-Driven On-Off Switches: Azobenzene and Anthracene Cyclophanes. $21,000

Graham B. Jones, Clemson U. Chiral Arene Chromium Tricarbonyl-Based Lewis Acids as Enantioselective Catalysts. $21,000

Frederick R. Lemke, Ohio U. Synthesis and Reactivity of Transition-Metal Silylene Complexes. $21,000

Gwendolyn L. Macpherson, U of Kansas. Bromide in Formation Water: An Organic Source? (An investigation of the magnitude of dissolved Br which could be sourced from organic matter, in Gulf of Mexico Basin and in Kansas). $18,000

Ann E. McDermott, Columbia U. Enzyme Dynamics and Catalytic Mechanisms by Solid-State NMR: The Photosynthetic Reaction Center and Triose Phosphate Isomerase. $18,000

J. Thomas McKinnon, Colorado School of Mines. Gas-Phase Oxidation of Aromatics by Singlet Oxygen. $21,000

Anne S. Meltzer, Lehigh U. Crustal Structure and Rock Properties Offshore Central California from Combined Vertical Incidence and Wide-Angle Seismic Data. $21,000

Kate C. Miller, U of Texas, El Paso. Deep-Penetration Seismic Reflection Studies of the California Continental Borderland. $21,000

Johannes M. Nitsche, State U of New York, Buffalo. Enhancement of Size-Exclusion and Hydrodynamic Chromatography by Tailoring of Porous Microenvironments, Flow Tuning and Stationary-Phase Staging. $18,000

Thomas S. Scanlan, U of California, San Francisco. New Methods for Improving the Efficiency of Catalytic Antibodies. $18,000

Kirk H. Schulz, U of North Dakota. Desulfurization of C_1 Organosulfur Molecules on MoS_2 Model Catalysts. $21,000

Vatche P. Tchakerian, Texas A&M U. The Investigation of Textural, Micromorphological, and Mineralogical Changes Associated with Sandy Paleosols and Their Eolian Parent Sediments. $18,000

Timothy L. Ward, U of New Mexico. Fabrication of Ultrathin Supported Nonporous Inorganic Membranes Using Chemical Vapor Infiltration. $21,000

Yue Wu, U of North Carolina, Chapel Hill. A Nuclear Magnetic Resonance Study of Small Clusters. $21,000

Gergely T. Zimanyi, U of California, Davis. Phenomenology and Microscopics of High-Temperature Superconductors. $18,000

Timothy P. Curran, C of the Holy Cross. Development of a Robust Prolyl-Proline Dipeptide α-Helix Template. $18,000

Steven M. Drew, Carleton C. Synthesis and Electrochemical Polymerization of Vinyl-Substituted Iron Porphyrins. $18,000

Gregory D. Foster, George Mason U. Supercritical Fluid Extraction Coupled with Gas Chromatography in the Trace Analysis of Organic Substances. $18,000

Carl H. Grossman, Swarthmore C. Second Harmonic Generation in Organic Molecular Single Crystals. $18,000

Paul G. Jasien, California State U. Computational Studies of Reactivity Enhancement by $AlCl_3$. $18,000

Sandra L. Laursen, Kalamazoo C. Selection of Spin Multiplicity in Matrix Photoreactions of NH with Hydrocarbons. $18,000

Richard S. Lumpkin, U of Alabama, Huntsville. New Chromophore Sensitizers for Liquid Junction Photoelectric Devices Based on Wide-Bandgap Semiconductors. $18,000

Nancy R. Riggs, Northern Arizona U. Analysis of Volcanic Detritus in the Lower Chinle Formation, Colorado Plateau: Source Areas and Influence on Basin Evolution. $18,000

Philip J. Rous, U of Maryland, Baltimore County. Theoretical Studies of Resonance Electron Scattering by Adsorbed Molecules. $18,000

Suzanne E. Sherman, U of South Florida, New C. Investigation of Metal-Carbohydrate Interactions: A Synthetic Analog Approach to the Active Site of Rubisco. $18,000

David W. Taylor, Indiana U Southeast. Investigation of Fossil Plant $\delta^{13}C$ and Changes in Coal $\delta^{13}C$ from the Paleozoic-Mesozoic to Cenozoic. $18,000

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type SE)

Harry R. Allcock, on behalf of ACS Division of Polymer Chemistry. Inorganic and Organometallic Polymers, ACS national meeting, Denver, spring 1993. $2000

H. Michael Cheung, on behalf of ACS Division of Industrial Engineering Chemistry. Polymeric Surface-Active Materials, ACS national meeting, Denver, spring 1993. $2000

Patricia A. Johnsson, William H. Casey, on behalf of ACS Division of Geochemistry. Mineral/Water Interface Geochemistry: Honoring Paul W. Schindler, ACS national meeting, Denver, spring 1993. $2000

George B. Kauffman, on behalf of ACS divisions of History of Chemistry, Inorganic Chemistry, and Chemistry Education. Coordination Chemistry, ACS national meeting, Denver, spring 1993. $2000

Thomas E. Mallouk, on behalf of ACS Division of Colloid & Surface Chemistry. Chemically Sensitive Interfaces, ACS national meeting, Chicago, fall 1993. $2000

Reginald H. Mitchell, on behalf of U of Victoria. Novel Aromatic Compounds, 7th International Symposium on Novel Aromatic Compounds (ISNA-7), Victoria, British Columbia, July 1992. $2000

Richard W. Ojakangas, on behalf of International Basement Tectonics Assn. and U of Minnesota, Duluth. Basement Tectonics 10th International Conference on Basement Tectonics, U of Minnesota, Duluth, fall 1992. $1700

Raphael M. Ottenbrite, on behalf of ACS Division of Polymer Chemistry. Polymeric Drugs and Drug Delivery, ACS national meeting, Washington, D.C., fall 1992. $2000

Hanna Reisler, on behalf of ACS Division of Physical Chemistry. Photochemistry from Isolated Molecules to Solutions, ACS national meeting, Washington, D.C., fall 1992. $2000

Norman W. Standish, on behalf of ACS Division of Petroleum Chemistry. Chemistry of the Atmosphere, Washington, D.C., 1992. $1000

Laren M. Tolbert, on behalf of The Inter-American Photochemical Society. The 5th Winter Conference of the Inter-American Photochemical Society, Clearwater Beach, Fla., January 1993. $2000

Nominations for Buck-Whitney Award

The ACS Eastern New York Section is soliciting nominations for the 1993 Buck-Whitney Award. The award consists of a medal and a $1000 honorarium. The nominee must be a resident of North America whose original work in pure or applied chemistry has not yet received national attention. The nominee's work can be in either experimental or theoretical aspects of any area of chemistry. Send nomination letters to Malcolm R. Bell, RD 1, Box 156A, East Greenbush, N.Y. 12061, by Nov. 1. ☐

Call for nominations for Spencer Award

The ACS Kansas City Section is soliciting nominations for the 38th annual Kenneth A. Spencer Award for Outstanding Achievement in Agricultural Chemistry. The award, which recognizes meritorious achievements in the fields of agricultural and food chemistry, is given in the hope of providing added stimulus to those engaged in research, education, and industry to continue to contribute to the advancement of agricultural chemistry. The award will be presented in February 1993. The recipient of the award will receive a medal and a $5000 honorarium. The deadline for submission of nominations is Sept. 1. Nomination forms and further information are available from Ernest Parente, chairman, Spencer Award, Marion Merrell Dow, P.O. Box 9627, Kansas City, Mo. 64134-0627, phone (816) 966-5000. ☐

Nominees wanted for Tyler Prize

Nominations are being sought for the Tyler Prize, the World Prize for Environmental Achievement. The award consists of $150,000. Nominees may be associated with any field of science. Prizes are awarded for either the protection, maintenance, improvement, or understanding of ecological and environmental conditions or for the discovery, development, improvement, or understanding of known or new sources of energy.

Nominations should include the name, address, title, affiliation, and vita or résumé of the nominee. Nominations of institutions should identify the administrative officer of the organization responsible for the contributions cited. In addition, a summary of the individual's or institution's contributions, a detailed description of contributions, and at least three letters of recommendation are required. Nominations are due Oct. 1.

Mail nominations to Jerome B. Walker, Executive Director, Tyler Prize, Office of the Provost, University of Southern California, Los Angeles, Calif. 90089-4019, phone (213) 740-6559, fax (213) 740-1313.

Nominations sought for analytical awards

The ACS Division of Analytical Chemistry Awards Canvassing Committee is seeking candidates for four awards given annually by the division. The Award for Excellence in Teaching is given to an individual teaching at the graduate or undergraduate level who has definitively and uniquely enhanced the professional and personal development of students in analytical chemistry. The awards in chemical instrumentation, spectrochemical analysis, and electrochemistry are given to individuals who have made original and eminent contributions to the advancement of their respective fields. Each award consists of $4000, a plaque or a certificate, and up to $1000 in travel expenses to attend the ACS fall national meeting at which the award will be presented.

Deadlines for submitting nominations are available from the committee. Eligibility for awards is not restricted to members of the Division of Analytical Chemistry, and nominating and secondary letters may also come from individuals who are not members. All nominations must be submitted by Sept. 1 to Charles L. Wilkins, Department of Chemistry, University of California, Riverside, Riverside, Calif. 92521-0403.

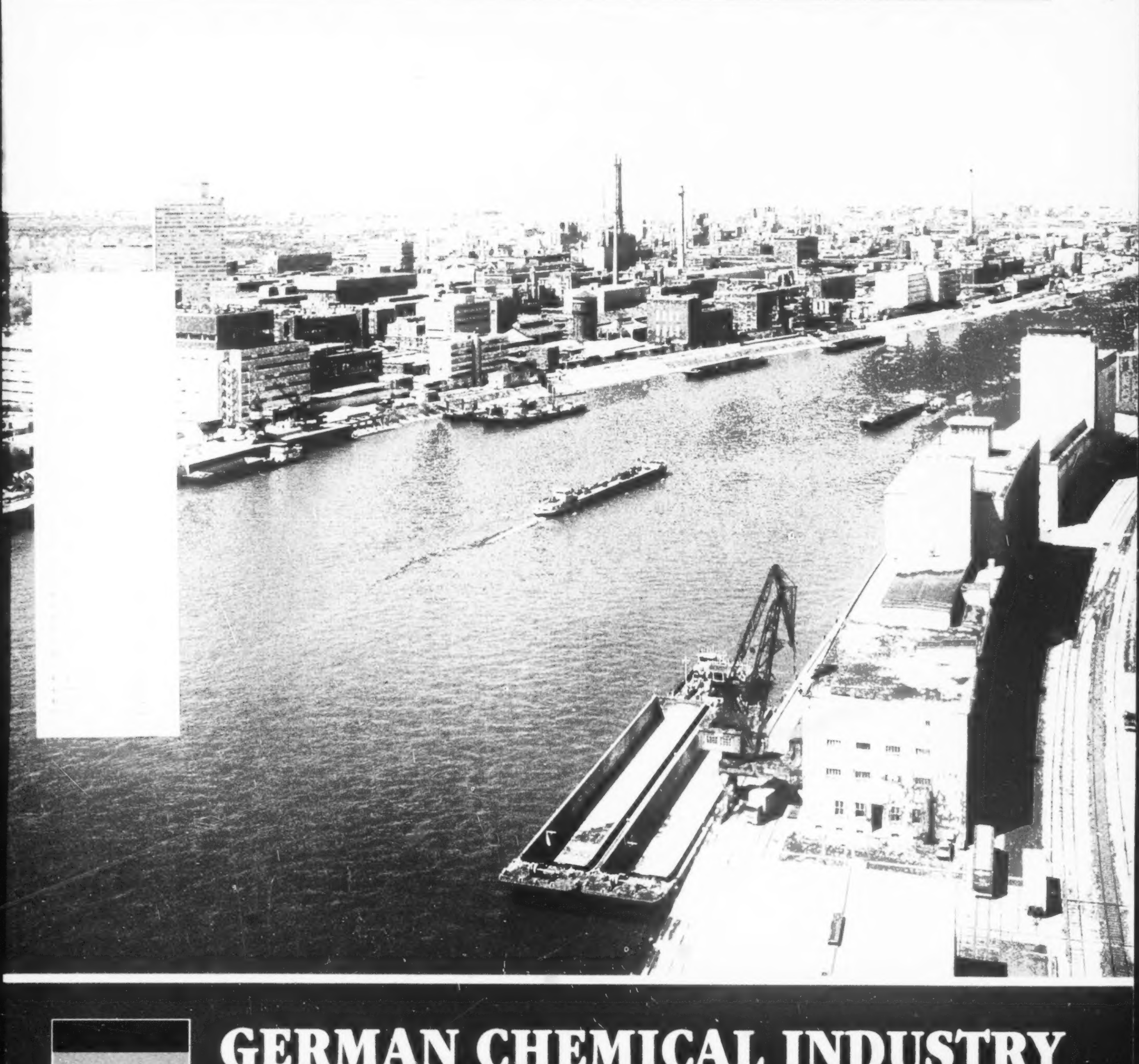
For further information, contact Philip J. Savickas, Analytical Sciences Laboratory, Dow Chemical Co., 1897F Bldg., Midland, Mich. 48667, phone (517) 636-8728, fax (517) 638-6443. ☐

CHEMICAL & ENGINEERING NEWS

C&EN

JULY 27, 1992

FINAL PROGRAM -- ACS NATIONAL MEETING IN WASHINGTON, D.C.



GERMAN CHEMICAL INDUSTRY

Attempts at unification fizzle out Page 7

CHEMICAL & ENGINEERING NEWS

C&EN

JULY 27, 1992

NEWS OF THE WEEK

- Biggest news from the International Conference on AIDS held in Amsterdam concerns reports of patients with AIDS-like symptoms but without HIV-1 or HIV-2 infection. Page 4
- NASA prepares for July 31 launch of space shuttle *Atlantis*, which will probe the use of a tethered satellite system. Page 4
- The U.S. team placed fourth, behind teams from China, Hungary, and Poland, in the 1992 International Chemistry Olympiad, concluded last week in Washington, D.C. Page 5
- Two candidates for directors on the ACS Board of Directors have been nominated by petition. Page 6
- Chemical companies showed some signs of financial recovery in the second quarter of 1992. Page 6

COVER: BASF's huge chemical complex at Ludwigshafen

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BUSINESS

Agricultural biotechnology firms extend their basic technologies to develop biological insecticides for common house and garden pests. Page 23

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Federal research labs' accounting practices are found to be lax, weakly controlled, and the cause of waste and misuse of millions of dollars. Page 26

Pilot program to aid female scientists who wish to continue their research careers after taking time off to raise children is initiated by NIH. Page 27

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Waste treatment method uses citric acid and bacteria to remove metals and radionuclides from soil, sludge, and sediments; new technique quickly identifies bacteria that will be most effective at metabolizing certain wastes. Page 35

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Aspects of genetic engineering that cause the public concern are subject of a collection of essays by a diverse group of science, government, and law experts. Page 37

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No petitions are scheduled for action by the ACS Council at the society's national meeting in August in Washington, D.C., but some are scheduled for committee discussion. Page 39

FINAL PROGRAM

ACS national meeting next month in Washington will feature more than 4200 papers in 504 technical sessions; exposition will comprise about 400 booths representing about 220 exhibitors. Page 41

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Attempts to unify the German chemical industry falter as environmental concerns and recession delay the process, but industry's strength likely will overcome these obstacles. Page 7

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
Robert H. Marks, Director, Publications Division

PUBLISHING BOARD: Ned D. Heindel *(Chairman); Board of Directors Chairman:* Joseph A. Dixon; *President:* Ernest L. Eliel; Richard L. Deming; Judith C. Giordan; William P. Jencks; and Gary J. Long

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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
(For list of offices see page 131)
Office of Ombudsman: (800) ACS-5558, No. 8–5
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LETTERS

Fluoridation controversy

Your recent review of Brian Martin's book, "Scientific Knowledge in Controversy: The Social Dynamics of the Fluoridation Debate" (C&EN, June 29, page 76), prompted me to share my own public experience with this debate. Last December, I was appointed to advise the mayor and city council of Tucson, Ariz., on the benefits and risks of fluoridating our municipal drinking water. It appeared to be a challenging and exciting opportunity for a scientist. I was not disappointed.

Tucson is a city of 600,000 inhabitants that has relied on groundwater as its sole source of drinking water for the past 100 years. Approximately 200 public and private wells supply 100,000 acre-feet a year. Next year, Tucson will switch from wells to Colorado River water, supplied by an aqueduct to a newly constructed central treatment plant. This switch will permit the water utility to add chemicals at a central facility in a uniform manner.

As soon as the date was set for the initiation of water treatment, the local county board of health requested that the city add fluoride to the drinking water. The board claimed that optimum amounts of fluoride (0.8 ppm) would prevent decay in teeth and especially benefit poor children. The board of health was immediately joined by state and federal public health organizations. The city referred this matter to my subcommittee.

As a loyal ACS member, my first act was to distribute copies of Bette Hileman's excellent review article on this subject (C&EN, Aug. 1, 1988, page 26) to all nine members of my subcommittee. Next, I recommended Brian Martin's book for background reading. The subcommittee decided to limit its review to the scientific aspects of fluoridation and not to review the ethical, moral, and constitutional issue of involuntary medication.

During the three months of public hearings that followed, our subcommittee was lobbied with mountains of printed material and verbal testimony. These sessions were emotionally charged by pro- and antifluoridation advocates. I was personally labeled a "John Bircher" by a profluoridationist and labeled a "lackey of the chemical industry" by an antifluoridationist. Every argument, every claim, every uninformed public health official, and every personality involved in the Tucson controversy was a mirror image of the stereotypes described in Martin's book. Even our own committee members gradually assumed some of the stereotypical roles in Martin's book.

From a thorough review of the published data, our subcommittee concluded that the field epidemiology extolling the benefits of fluoridation was uneven and flawed. The same conclusion applied to the counterclaims of massive risks. We could draw no definite recommendations from these data.

However, the city of Tucson provided us with a unique opportunity to test the fluoridation hypotheses. Historically, this city has had discrete geographic areas of groundwater with high fluoride content (0.8 ppm) and areas of low fluoride content (0.3 ppm). Our committee had access to a recent dental screening of 26,000 elementary school children. When we plotted the incidence of tooth decay versus fluoride content in a child's neighborhood drinking water, a positive correlation was revealed. In other words, the more fluoride a child drank, the more cavities appeared in the teeth.

Since this was an unusual result, our subcommittee looked for other relevant factors. Family income was compared to tooth decay. An excellent inverse relation was found for these 26,000 children: the higher the income, the lower the number of decayed teeth. Other anecdotal evidence gathered by our committee included lack of access to dental facilities, poverty, diet,

Corrections

- June 29, page 26: The work on redox-dependent molecular recognition in proteins had two principal investigators, Alan F. Corin, senior scientist at Eastman Kodak's corporate research laboratories, as well as chemistry professor George L. McLendon at the University of Rochester. Both are affiliated with the NSF Center for Photoinduced Charge Transfer at the University of Rochester.
- July 6, page 21: California's South Coast Air Quality Management District has proposed trading nitrogen oxide emissions allowances, not nitrous oxides.

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BUSINESS CONCENTRATES

Centocor reports loss, cuts staff under new plan

Centocor, the Malvern, Pa.-based biopharmaceutical company, is implementing a new business plan after rearranging its management and reporting a major loss for the first quarter of 1992. The $45.8 million loss included a special charge of $9 million to account for inventories of the company's monoclonal antibody product, Centoxin. A delay in FDA approval has been a major blow to the company's launch of Centoxin in the U.S., but the firm markets this and other products in Europe. In early May, Centocor rearranged its management team (C&EN, May 4, page 7) and now has a new collaborative strategy that includes forming alliances with established drug companies. The company will continue to reposition itself throughout 1992 with the goal of achieving profitability by the end of 1993. As part of its plan, staff will be cut at Centocor's headquarters and at manufacturing operations in Leiden, the Netherlands, and in St. Louis. The cuts will involve 225 people, or 15% of the company's employees.

Dexter to sell water treatment unit

Dexter Corp., Windsor Locks, Conn., has agreed to sell its water treatment division, Mogul Corp., to Diversey Corp. of Mississauga, Ontario. Diversey is part of the Canadian Molson Companies Ltd. Mogul, headquartered in Chagrin Falls, Ohio, had 1991 sales of $44 million and reported a profit. The division has facilities in Charlotte, N.C.; Phoenix; and Canada. The sale, which is expected to be completed in June, is likely to result in a capital gain for Dexter. In 1990, Dexter sold the European and Australian operations of its water treatment business to W. R. Grace.

Glitsch and Petrocel collaborate on DMT process

Dallas-based Glitsch Technology and the Mexican firm Petrocel have agreed to jointly develop and market improved dimethyl terephthalate (DMT) production technology. The two companies hope to fill a gap they believe exists as a result of Dynamit Nobel's and Hercules' discontinued development and licensing of DMT technology. Because DMT is a mature product, Glitsch and Petrocel will focus on increased yields and reduced energy consumption for its production. Development work will be conducted at Glitsch's R&D centers in Texas and Montana. Demonstration units are to be constructed at Petrocel's Altamira, Mexico, plant. DMT is one of two major feedstock materials for polyester production. As part of the Grupo Industrial Alfa, Petrocel is one of the world's largest producers of DMT.

Unocal completes polymers sale

Unocal has completed the sale of its emulsion polymers business to Rohm & Haas after overcoming Federal Trade Commission (FTC) objections. Sale price of the business was about $175 million. Philadelphia-based Rohm & Haas immediately sold the part of the business that makes acrylic polymers for architectural coatings to Union Carbide for an undisclosed sum. This move was made to satisfy FTC objections to the deal. Unocal reported 1991 sales for the emulsion polymers business were about $145 million. The polymers included in the transaction are sold to companies that produce paint, paper, textiles, adhesives, and carpet. Unocal's deal with Rohm & Haas includes six U.S. plants and a technical center in Charlotte, N.C. Carbide will receive technology for three acrylic coatings products and customer lists, but no manufacturing facilities. Product will be supplied from Unocal plants for up to one year as Carbide gears up for production.

BP Chemicals to sell specialties unit

Hythe Chemicals, a specialty chemicals unit of BP Chemicals, has been acquired by International Specialty Chemicals, a U.K.-based holding company, for an undisclosed price. Purchase of the unit is expected to be completed by the middle of the year. Involved are specialty monomers and plasticizers produced at Hythe, on the south coast of England. Associated businesses are also included in the sale.

Net profits up 78% for Rhône-Poulenc

Net after-tax profits for this year's first quarter at France's Rhône-Poulenc were $138 million, up 78% from those of the gloomy comparable period in 1991. Consolidated sales rose 3% to $3.86 billion. The company says although the economic climate remains unfavorable, improvements in productivity following restructuring in all the company's businesses have improved its profitability.

Courtaulds continues its profits growth

Courtaulds, the British specialty materials company, increased after-tax profits 5% for its fiscal year ended March 31, 1992, to $263 million. Sales for the company grew almost 2% from the previous fiscal year to $3.37 billion. Courtaulds had particularly good results in its fibers and films division, following its withdrawal from loss-making businesses, and as a result of a better balance between supply and demand in some areas. The company also noted that its new $85 million plant to make Tencel viscose fiber in Mobile, Ala., will be commissioned early next month.

Chemicals sag but stay in black at Shell

First-quarter 1992 chemical earnings for Netherlands-based Royal Dutch/Shell fell 76% from last year's first quarter to $36.5 million, and chemical sales slid 9% to $2.46 billion. Virtually all the chemicals profits came from U.S. operations; operating profits outside the U.S. were almost nil, compared with about $100 million in the past year's comparable period. Profitability declined, the company said, both because industry overcapacity has depressed selling prices, and because of depressed markets, particularly for bulk petrochemicals.

Hercules Chairman Gossage Sets Course for Growth

■ ***Divestitures, joint ventures, and emphasis on core businesses aim at leading troubled firm to higher profitability***

Marc S. Reisch,
C&EN Northeast News Bureau

Hercules chairman Thomas L. Gossage has no delusions about the company he inherited in January last year. It needs more fixing.

Gossage—the first Hercules chairman who did not begin his career at the company (he spent 26 years at Monsanto before joining Hercules in 1988)—is not shy about saying that businesses that cannot contribute earnings above the cost of capital will have to go. His statement put the company's resins and polypropylene film managers on notice, and resins in particular have begun to show a return to profitability.

Gossage is also not afraid to suggest that although Hercules has millions of dollars invested in the rocket motor business, it is a likely joint-venture candidate, should the right partner turn up. The same is true of the company's carbon fibers business, which, like rocket motors, is now in something of a rut, along with other businesses highly dependent on military and commercial aerospace contracts.

And Gossage says Hercules has been spending too much money on R&D and capital projects. This is changing even now. Money put into future-oriented projects will more closely reflect the company's financial capabilities.

But he is quick to note Hercules' successes last year: Cash flow was positive after being negative in 1990; reductions in personnel yielded $50 million in savings; operating profit as a percentage of sales grew to 6.4% from 5.9% in 1990; and employee morale improved.

Despite the difficult economy of 1991, Gossage says that "Hercules showed a considerable amount of improvement, and I think that we will continue to show that kind of improvement in 1992 and beyond. I don't think all our problems are behind us, but I think we have taken some major steps forward to become again what we once were—a good chemical company."

In the years between 1987 and 1990, the Hercules aerospace business faltered. The company also lost share of market in polypropylene film, and sold or shut down a number of businesses, including Simmonds Precision Instruments, polypropylene cigarette filter tow, and synthetic pulp. Hercules was ready for a change, says Gossage. "I firmly believe getting a few good years back to back is going to change the attitude of almost all employees and shareholders."

Operating profits before special charges rose 34% to $255 million in Gossage's first year at the helm. Although the improvements in earnings might not be so dramatic in the future, Gossage hopes they will continue to rise. In the past, he says, "we pulled ourselves into a shell and did not want to act out of fear of making a mistake." But that has already begun to change, he says, as employees "are more willing to step out and take risks. . . . I think that those [companies] who take reasonably prudent risks make the difference between the reasonably successful company and the not-so-successful company."

C&EN staff photo

Gossage: some major steps forward

Some outside observers also believe that with the employee reductions Hercules began to take last year, along with the sale or shutdown of underperforming and nonstrategic businesses, Hercules is indeed becoming a more successful company. Analyst James Wilbur, managing director of stockbroker Smith Barney, says he thinks the outlook for the company is favorable, and only a few weeks ago issued a buy recommendation for the company's stock. Hercules' stock has risen about 7.3% since the beginning of the year to $53⅛ per share compared with a 4% rise for the seven major chemical companies (including Hercules) that make up C&EN's own chemical stock index.

Credit analyst Bruce James, assistant vice president of Moody's Investor Service, says Hercules' chemicals businesses in particular have "turned around nicely." Excluding unusual charges, 1991 was the third year in which the company showed improved operating margins. In fact, says James, they were the best results Hercules has delivered since the mid-1970s.

Other analysts, however, are puzzled over just what kind of company Hercules really is. One stock analyst tells C&EN that "Hercules has become an orphan," because it has transformed itself and taken so many different directions in the past 10 years. The analyst specifically refers to Hercules' numerous joint ventures with Montedison, ranging from the polypropylene joint venture Himont (which it finally sold off to Montedison in 1987) to Moplefan, the European-based polypropylene film and fiber venture. Also mentioned is the company's confusing forays into aerospace electronics and instrumentation. Business analyst J. Charles Forman of Forman Associates Consulting & Technical Services, Darrien, Conn., says quite bluntly: "If they could get rid of those rockets, they would have a much better company."

But Hercules' chairman says he is not about to jettison the aerospace business. "I certainly do not want to imply that we have become disenchanted with aerospace," he says, even as he acknowledges that Hercules continues to have problems with its aerospace business. Among those problems: the Titan IV rocket motor business. In 1989 Hercules took a $323 million write-off largely related to the Air Force's missile program. A test of the motor failed a year ago, but Hercules is betting that a test scheduled in the next few weeks will be more successful.

Gossage says aerospace "is an important segment of our business. I think it can be a healthy and significant contributor." But it might better contribute to Hercules' earnings as an unconsolidated affiliate. "I certainly would not discount the possibility of some sort of joint venture or alliance with somebody somewhere along the way." However, that will not happen immediately, says Gossage. Hercules is still determined to make a success of Titan, "so through 1992 I see us [as] a very significant chemical company trying to position ourselves more effectively in [the chemical] industry," while the company also works to make its aerospace business more profitable.

On the chemicals side of its business, the Hercules chairman says that when he took over the company a year ago, both polypropylene film and resins were operating "with returns certainly below our cost of capital." A year later "our resins business has stepped up to the challenge" of producing higher returns, and "made a significant contribution to our income in 1991." On the other hand, says Gossage, "our polypropylene film business has attempted to make that same kind of move forward with less success."

Hercules ultimately may decide not to sell either its resins or its films business, says Gossage. They are both moving to a position where they will allow Hercules to reach its goal of a 14% return on stockholder equity in the next five years—far higher than the 5% return in both 1990 and 1991. Its return on equity in first-quarter 1992 was 7.8%.

Smith Barney's Wilbur thinks Hercules' 14% goal is a reasonable, if modest, one. He points out that others in the chemical industry have higher goals. Du Pont's goal is 16%, Monsanto's is 20%, PPG's is 18%, Engelhard's is 15%. Average return on equity of the companies that make up the Standard & Poors 500 is 15%, he points out. "You can't expect everyone to be above average," says Wilbur, "but this puts them a little below average."

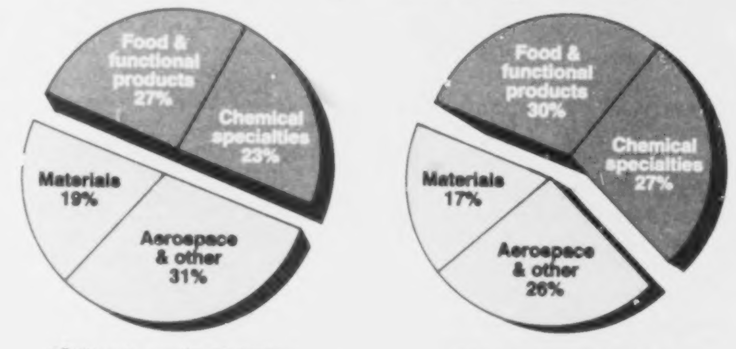
A significant factor in Hercules' efforts to improve its return to stockholders is its aim to operate more efficiently. Employee cutbacks in the range of 2500 over the past year helped "take over $50 million out of our indirect [cost] base in 1991," says Gossage. Capacity rationalizations and productivity gains, particularly in resins but also in other businesses, such as aerospace, also helped reduce the company's costs, he says. And Hercules has pushed to get "decisions made within the organization at the lowest possible level. . . . We were not, in fact, a company that was holding our people accountable for cash flow prior to 1991, which is pretty amazing."

To improve its competitive position, Gossage says Hercules will continue to look into joint ventures. The company recently completed a flavors and citrus specialties joint venture with Imcera, which "is an example of two very profitable, very attractive flavor companies that were not significant players" in the business. By putting them together, he says, "we now have a company that is indeed a significant player, and I think it is going to be a major flavor house in a couple of years. We would like to do more of that sort of thing."

In addition to a possible aerospace joint venture in the future, Gossage says Hercules recently discussed a joint venture of its carbon fiber and composites businesses with an unnamed partner. However, the proposed venture did not work out. "We had very serious discussions under way," he says, for creating an alliance with another company in which it brought certain strengths and Hercules brought certain strengths. "With the rationalizations that are taking place in advanced materials, it would have been a major move."

James L. Ma, a senior consultant for SRI International, suggests the reason Hercules and others might consider combining carbon fiber and composites businesses with those of a competitor is that today these businesses are growing more slowly than they once were. They are now affected not only by government defense cutbacks and commercial aerospace slowdowns, but also by stagnating markets such as sporting equipment. And new markets such as composites for use in auto parts have never developed as was hoped. That is true not only because of high carbon fiber prices ($10 to $12 per lb for some grades), but also because of the complex fabrication techniques necessary to form parts.

Food products, chemical specialties are growth areas



"I think our commitment in Bitterfeld, which was not easy for us in the present economic climate, shows we are facing up to our responsibility," Strenger added.

Much of the investment spending in the eastern states is going toward environmental cleanup and modernization—steps the German chemical industry is already familiar with in the western states.

Hoechst is a typical example. Its operating costs for all units involved in environmental protection last year were $662 million, with another $125 million invested for the purpose. More than 680 employees work full-time in the environmental protection sector, the company reports.

In Germany alone, Hoechst is operating 22 large-scale wastewater treatment units. At the company's home complex near Frankfurt, it will soon be installing a further cleaning stage for the flue gas from its residue incineration plant and it is working to set up material recycling schemes. It has already started projects to recycle polypropylene, polyvinyl chloride, polyacetal, and polyester, and its chlorofluorocarbon refrigerants are to be marketed with a "take-back" guarantee.

After considerable debate, the German chemical industry has adopted the rubric of the Responsible Care program to cover its industrywide environment, health, and safety program. Among the reasons for the debate and delay is the firm belief among many German chemical manufacturers that the Responsible Care program, sponsored by the U.S.'s CMA and similar associations in other countries, represents an actual lowering of standards from the German "Chemie im Dialog" public commitment.

The industry is proud of its pollution reduction record. For example, it has reduced organic contaminants and heavy metals in its effluents by more than 90% during the past 25 years, although production of all chemicals has almost tripled. Between 1979 and 1990, sulfur dioxide emissions to the atmosphere were trimmed 69%, nitric oxide emissions 54%, and organic compound emissions 66%. In 1990, companies created an association to develop a recycling system for plastic materials and to promote recycling and the marketing of recycled products. Despite the current low prices of petroleum and natural gas, the industry has not suddenly developed wasteful habits, squandering energy in its processing and plant operations.

Considering the chemical industry's past efforts, many in the industry feel a sense of aggrievement as state governments pass more and more regulations and laws concerning environmental standards.

Bayer's Strenger, for one, has called for a period of consolidation for laws to be sorted out and implementation plans developed. As he told shareholders in April, "I am worried about the disproportionate rise in environmental protection costs, which no longer bear any relation to the benefits they bring and are endangering our competitiveness. We are not asking for standards to be lowered—we want to see further progress in this field. But we do need a different environmental policy if we are to achieve this."

Among the environmental moves affecting the industry is the campaign of the federal environment minister, Klaus Töpfer, to transform the German society from a "throwaway" society to one devoted to recycling. Key to his campaign is a new set of laws that force manufacturers and distributors to take back the packaging for their products, and the products themselves at the end of their useful lives.

By the beginning of next year, for example, 50% by weight of all packaging must be collected, with 30% of the plastics, 70% of the glass, 65% of the tinplate, and 60% of the aluminum, paper, and cardboard recycled. That effectively translates to about 2.4 billion lb per year of plastics alone, if the targets are met. Moreover, by July 1995, the totals increase to 80% of packaging materials to be collected, with the reprocessing of 80% of plastics, and 90% of glass, tinplate, and aluminum.

Strube: innovation stifled

Incineration will not count as a reprocessing method, although the German government accepts the concept of chemical recycling, if it can be worked out economically. Incineration of plastic waste would have been the answer to meeting the target date, chemical companies believed—BASF, for one, was developing a scheme for deriving energy from the incineration of plastics. Now, the industry—as the ultimate supplier of plastic materials—is turning to developing technology for chemically recycling polymers for reuse. Under the aegis of the German Association for Recycling Used Plastic Packaging, the chemical industry recently sponsored what was termed a "successful large-scale experiment," at a coal-oil installation in Bottrop, Germany, where oil residues from crude-oil refineries are processed. The mixed and soiled plastic waste from household garbage was converted by hydration into high-quality oil that in turn was treated at the Ruhröl Refinery in Gelsenkirchen, for use as plastics feedstocks.

The green dot system—devised by Duales System Deutschland for recovering packaging waste and by which a green dot is placed on recyclable packaging—still has a long way to go to meet the targets set by Töpfer, who has ruled out any time extensions. Current recycling capacity is being swamped, and even the prospect of constructing several new recycling plants won't help all that much—the total capacity by year's end is expected to be about 220 million lb per year, or only about one tenth of what is needed. One result is a slowdown through the chain of product manufacture, distribution, and sale. Another is the export, still legal, of collected wastes to other European countries, in turn overwhelming recycling facilities and markets for recyclable waste in those countries.

Another major concern for the industry is the threat of a federal carbon tax, a levy on carbon dioxide emissions, which would be significantly higher than the tax proposed by the Commission of the

European Community, which would effectively add $10 to the price of a barrel of oil by the end of the century.

"The energy consumption of our industry—the energy consumption per thousand deutsche marks of gross value added—has been strongly reduced during the past 30 years: with electricity, it dropped by 40% and with fuels, by 75%," according to Hilger. "To bring about such achievements, we do not need any targets stipulated from the outside," particularly as part of a national, rather than international or global, effort to tackle environmental problems, he said.

Other industry executives join Hilger in his arguments against such a uninational tax. It is scientifically irrational, they say, and economically unworkable. However, privately, others in the industry gloomily expect a carbon tax to be passed anyway. The prospect of handsome tax revenues will be too enticing for politicians to turn down on mere scientific grounds, they predict.

If such a tax is passed, it will be just one of the burdens with which the German chemical industry will have to cope. Another is the increasing challenge to prevent erosion of the country's hard-earned productivity through escalating social and employment costs.

For example, VCI began its rounds of negotiations with labor unions shortly after Germany was racked by public-sector labor strikes that were settled with contracts featuring a 5.4% wage increase. VCI, working through the Bundesarbeitgeber Verband Chemie—the Association of Chemicals Employers—reached a basic 5.1% settlement with the chemical union, the IG Chemie. Included was an agreement to trim the workweek gradually from 39 hours to 37.5 hours by 1996.

"There has been a very realistic relationship between the chemical industry and the union, for a very long time," observed one industry executive. "Our workers have benefited from this."

It remains to be seen, however, whether this "realistic relationship" changes in the future: IG Chemie is in the process of merging with the union of miners, considered a highly aggressive union. Said another negotiator: "We are anxious to see what culture emerges. What we have had so far is a good, results-oriented relationship. Efficiency has been very important on both sides."

Such challenges are encouraging the German chemical industry to proceed in its shift within Germany from bulk and basic chemicals to higher value-added and fine chemicals. Pharmaceuticals, for example, now make up the largest single sector in the German industry. Bulk plastics are being de-emphasized in favor of more specialty polymers. And the industry has almost completely phased out its fertilizers operations.

Of Germany's Big Three companies, only Bayer—with the largest involvement in pharmaceuticals—did not trim its dividend to shareholders in 1991. Although its profits dropped slightly, the drop was not so large as the profit declines from 1990 were for the other two. And Henkel, with its extensive consumer-product businesses in detergents and personal care products, showed an increase in profits for the year.

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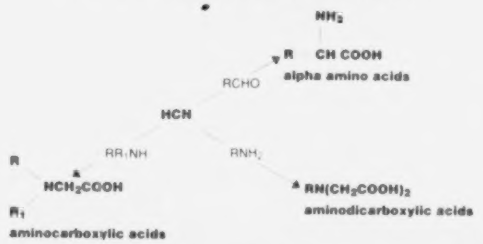

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In fact, Henkel's Winkhaus, when asked about current business levels, said: "We are content. The start of 1992 is a good start," with sales up 16% for the first quarter. "Maybe it won't keep on at that rate through the year—a recession is coming up in Germany, and that is our most important market." Nonetheless, he is optimistic about 1992.

That is not to say that German chemical companies are pulling out of the bulk chemicals business—only that when it comes to Germany itself, they are changing their investment strategy.

For example, BASF, the most bulk-oriented of the Big Three, says that logistics are playing an increasingly important part in making investment decisions. The company's basic chemicals division, for example, operates out of many sites, including its home base in Ludwigshafen—often touted as the largest chemicals complex in the world—as well as in Antwerp, Belgium; Geismar, La.; Pernis, the Netherlands; and Guarantinguetá, Brazil.

Company officials pointed out that it is more expensive to supply Ludwigshafen, an inland river city, with raw materials than to supply a site on the coast. Antwerp, on the other hand, is close to the sea, with access to competitively priced supplies of raw materials and energy. "It is no wonder that most of the substantial volume of the division's capital expenditures are being allocated to Antwerp," said a company planner.

In part, investments outside Germany are sound marketing decisions. As Winkhaus pointed out, "We have to follow the customers and take our production close to them," an important point as the German industry—like the chemical industry elsewhere—becomes more and more international. But also in part, they are a reflection of the political climate that has developed during the past several years in Germany.

To some extent, the political climate is a function of direct action by the various governmental bodies—state and federal—within the country. Companies cite the plethora of environmental regulations, for example, that they must cope with. Sometimes, it is a function of action and inaction: For example, authorizations needed for new plants or new processes drag out, causing problems with marketing and investment plans.

Said one chief executive: "If a marketing plan says a plant must go on stream in two years, and in Germany approval

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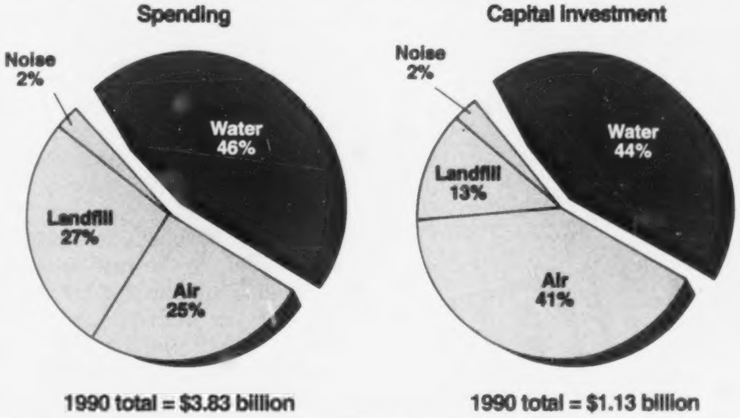
could take four years whereas in Belgium it would take two, this difference in timing plays a big role in making decisions. Our managers are reacting rationally, doing the job as best they see it."

BASF's chairman Jürgen Strube agreed. "It stifles innovation when authorities take far too long to evaluate projected production plants," he said. "Processing applications for chemical plants takes considerably longer in Germany than it takes at any other European sites."

Stube's colleague Wolfgang Jentzsch, a BASF director, noted: "We are not an industry that can just pack up its sewing machines, ship and install them in a simple shed in Thailand several weeks later, and then continue to manufacture shirts there. We cannot simply move our ammonia plant or steamcracker from Ludwigshafen to Antwerp, but also not vice versa. Once these new plants are built in Antwerp rather than in Ludwigshafen, they will stand there for 20 to 30 years to come, continuing to serve as a powerful magnet for users of these basic chemicals."

Water dominates chemical industry's environmental costs



Note: For former West Germany. **Source:** Verband der Chemischen Industrie

Even where local or state laws have been superseded by federal legislation, however, there can still be problems. The cause célèbre for the German chemical industry is biotechnology—specifically, the field of genetic engineering.

Until 1990, legislation concerning the field—a highly emotional one for Germans still living with memories of the Nazi past—was fragmented, conflicting, hesitant. Federal legislation designed to establish a framework to promote industrial use of this technology was passed in 1990. But it hasn't quite worked.

Bayer's Strenger can be thoroughly detached about the subject. His company elected early on to concentrate its genetic engineering research in the U.S. "Our decision to expand our involvement in this new technology in the U.S. was partly influenced by our disappointing experience with genetic engineering in Germany," he said.

"The way the German authorities have handled this legislation has so far failed to create the clear-cut legal situation that is so badly needed," he continued. "The position in the U.S. is completely different. The Americans have realized that industrial use of genetic engineering needs to be promoted as much as possible in the interest of the country and its economic development. It is to be feared that Germany will lag behind in this technology of the future; it may already have lost so much ground that it will not be able to catch up with other countries."

For Hoechst and Hilger, the challenge—and frustration—has been more direct. The company worked through the latter half of the 1980s for planning consent for a new biotechnology unit, but even with the national legislation no approvals came. Hoechst finally gave up on getting German authorization and decided to concentrate its genetic engineering work in the U.S. and Japan.

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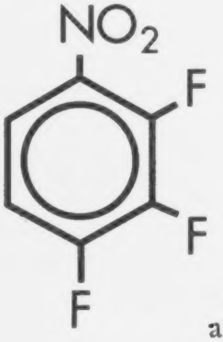

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Hence, at his press conference in Bonn, Hilger's comments on the subject had a certain bite, as he argued on behalf of VCI before the country's political press. "Two years ago," he pointed out, "the genetic engineering act was adopted with the objective to secure the safe development of this technology of the future. The chemical industry expressly welcomed the act, because it offered reliable framework conditions for our activities." The results were different however. "Our experience shows that the restrictive, bureaucratic, and overloaded enforcement of the act—that public authorities do not even uniformly apply on the federal level—paralyzes development." Nothing is happening in the sector, he said, not in industry or in university research.

"Reasons for the rejection of genetic engineering are most probably the fantastic ideas and the perfectly wrong contexts in which this subject is discussed in Germany," he suggested. Such industrial applications as genetically modified enzymes and pharmaceutical products and diagnostics have become intermingled in people's thinking with prenatal diagnostics, artificial insemination, genome analysis, and embryo protection.

"A clear differentiation is necessary, both in assessment and in action. Are important products and future-oriented processes to fail because socially binding solutions can be found for other issues?" he asked. "And what about production? Why should it be built up in Germany? Certainly not for reasons of logistics. The annual production of a genetically engineered active substance used in the pharmaceutical industry, a hematogenic hormone, can be sent in an airmail letter from Japan to Germany. But it is plain to see that the creation of value will remain in Japan."

The problems aside, however, the German chemical industry is fully aware of the strengths it already possesses, both within the country and as an industry. And as the recession forces companies to trim labor, shed out-of-date processes and capacity, and operate more tightly, the industry expects to remain competitive.

The current social and financial unrest running through the country following the unification of eastern and western Germany will fade, executives agree. It has been a painful, but necessary, experience. The economy will slow somewhat this year, particularly following the Bundesbank's efforts to curtail inflation by keeping interest rates high. But the slowing will enable chemical manufacturers to turn some attention to the export market once again, after frothy domestic demand led to more emphasis on imports during the past several years.

Indeed, as the unified market settles down, the German chemical industry will have an even better position in the center of Europe to influence or supply the markets opening up in the Eastern European countries. That is a long-term goal, of course, given the current conditions in the former East bloc—but the German chemical industry intends to be around, as a very tough competitor, for the long term. ☐

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CHEMICAL & ENGINEERING NEWS
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CARBON FIBERS, HURT BY MILITARY CUTBACK, SEEK NEW MARKETS PAGE 16

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NATURAL GAS

rowing importance in Asia as fuel and feedstock
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CHEMICAL & ENGINEERING NEWS

C&EN

AUGUST 3, 1992

NEWS OF THE WEEK

- In landmark fair use decision, a federal district court judge rules that photocopying copyrighted scientific materials requires compensation to journal publishers. **Page 4**
- New process that encapsulates natural insect or synthetic pesticides with mixture of starch and dispersants makes pesticides less likely to evaporate or wash off plants. **Page 5**
- Surveys by two environmental groups show that tracking toxic emissions of industrial plants outside the U.S. may be difficult unless countries enact right-to-know laws. **Page 6**
- U.S. and Japan launch Geotail spacecraft on a four-year mission to explore Earth's magnetosphere. **Page 6**

COVER: Process area of Southeast Asian liquefied natural gas facility. Photo courtesy of M. W. Kellogg Co.

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BUSINESS

Carbon fiber producers seek new markets as military orders decline and commercial aerospace uses are slowed by recession; a number of industrial, automotive, and sports markets are targeted for growth. **Page 16**

Train derailment in Wisconsin was not fatal; however, claims for minor injuries and business losses have been costly. **Page 18**

U.S. textile chemical growth will be slow and steady over the next five years, predicts a recent marketing study. **Page 18**

GOVERNMENT

Senate passes municipal waste bill that allows states to limit imports of trash from other states. **Page 22**

Negotiations to strengthen the Montreal protocol roiled over proposed change to multilateral fund set up to aid developing countries pay for ozone-safe technologies. **Page 23**

NIH readies final version of strategic plan for its future and expects to present plan to Congress by summer's end. **Page 23**

SCIENCE/TECHNOLOGY

Quantum mechanical method for simulating the hydrogen exchange reaction produces theoretical results that closely match experimental data. **Page 25**

U.S.-Russian cooperation in science and technology-related areas has been spurred by recent visits of several U.S. delegations to Russia. **Page 26**

New reagent that traps nitric acid is likely to have an impact on both environmental chemistry and medical research. **Page 27**

NEWS FOCUS

Use of natural gas in Asia, both as fuel and as chemical feedstock, is growing and is seen as an important factor in economic development in the region. Page 7

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LETTERS

Gene patenting

In the article "Critics Take Aim at NIH's Gene Patenting Strategy" (C&EN, June 8, page 21), the critics appear to be speaking from a standpoint of ignorance of the patent system. The simple fact is that the National Institutes of Health, by obtaining patents on expressed sequence tags (ESTs), will be able to effect whatever policy it ultimately determines is the best for the public good. Absent NIH's patenting strategy, the risk increases that private (and perhaps foreign) concerns will control patent rights, and that those concerns, not the government, will be in the position to edict under what terms and conditions the fundamental technology can be used.

Let's review the implications of NIH's applying for and obtaining patents. First, NIH has absolute discretion to determine what it wishes to do with its patent rights. NIH may dedicate those rights to the public or exclusively or nonexclusively license the patents to further developers (with or without royalty payments).

Second, the patent applications filed by NIH, upon becoming patents, constitute part of the prior art as of the date that they were filed. Thus, inventions of others must be novel and unobvious over the disclosure in the NIH patent applications. As those familiar with patents recognize, a patent disclosure is unlike a reviewed paper in a scientific journal. The inventor is legally required to make an enabling disclosure and reveal the best mode. But also in crafting a competing legal document, the inventor is wise to disclose the outer reaches of the scope of the invention. Even if not scientifically proven, information that the inventor believes to be true is legally acceptable in patent applications. This unproven information, not typically presented in technical papers, also becomes part of the prior art over which others must hurdle in order to obtain a patent. Thus, the patent application can be a much more effective document than a technical paper in preventing others from obtaining patents.

Third, seeking patents does not necessarily inhibit the exchange of technical information. A major reason not to disclose information about an invention prior to filing a patent application is that the recipient of the information may use it to seek patents on related inventions. Thus, whether or not it has a policy of seeking patents, NIH needs to reflect upon the extent of open exchange of information that it finds desirable.

In conclusion, the well-intentioned critics of the NIH patenting strategy, should they prevail, may find their position leading to exactly the result that they wish to avoid: Patent owners having exclusivity in the field of EST technology. The patent will be owned only by private entities, not by the government. The patent system, as it now exists, provides a tool that, if used benevolently by NIH, can maximize benefit to society for the emerging EST technology. I encourage James Watson and other opponents of the NIH patenting strategy to focus on what is best for society as a whole and not on the mechanisms for achieving that benefit.

Norman L. Balmer
Danbury, Conn.

Mo cumylcarbene catalyst

I wish to correct a statement in the Science/Technology Concentrates section concerning the formation of cyclic ethers by olefin metathesis (C&EN, June 29, page 26). The article states that a "commercially available molybdenum cumylcarbene catalyst" was employed. The catalyst, an $OCCH_3(CF_3)_2$ derivative, which was designed and synthesized in my laboratory, unfortunately is, to my knowledge, not commercially available. The $OC(CH_3)_3$ derivative is expected to be available soon from Strem Chemicals. Those who would like to explore the possibility of obtaining samples of the $OCCH_3(CF_3)_2$ derivative should contact David Hamm at Catalytica Associates, Mountain View, Calif., or prepare a sample by a newly published, relatively straightforward procedure [H. H. Fox et al., *Inorg. Chem.* **31,** 2287 (1992)].

Richard R. Schrock
Frederick G. Keyes Professor of Chemistry
Massachusetts Institute of Technology
Cambridge, Mass.

'Quasifood'

The Product Report by Ann M. Thayer (C&EN, June 15, page 26) is excellent, except for the title, "Food Additives."

"Quasifood" is far better than the old saw devoid of meaning. As a prefix, "quasi" means "having the characteristics of or certain of the qualities of"—to name but a few. So, let's drop the word "additives."

Jack DeMent
Portland, Ore.

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Natural gas offers industrial growth opportunities to developing nations

A usual assumption by economic planners and analysts is that the ready availability of fossil fuels, especially in developed countries, is the driving force behind industrial growth. It is further assumed that the developing countries of the world will develop similarly, if they have the requisite energy. A developing country is defined by the World Bank as one with a per capita gross national product of $5999 or less.

Detailed analyses of reserves and consumption indicate developing countries have about 40% of the world's natural gas reserves and 60% of the world's oil reserves. However, according to Donald L. Klass, retired vice president of the Institute of Gas Technology in Chicago, development and domestic use of these reserves has occurred in only 10 such countries: Algeria, Argentina, China, Hungary, Indonesia, Iran, Mexico, Pakistan, Poland, and Venezuela.

Even where gas reserves may be small by world standards, they are usually rather large for the domestic markets they could serve. The implication is that these gas reserves might be used well by domestic markets.

Although the bulk of the natural gas reserves are located in oil-exporting countries, significant gas reserves also exist in 30 developing countries that import oil. Thus, Klass says, there are substantial opportunities for developing countries to benefit from domestic gas reserves.

The expansion of natural gas use in these countries has often been the result of government policies rather than grass-roots entrepreneurship. The main reason for such expansion is to permit development of energy-intensive industries, which are the basis for economic growth—for example, steel, petrochemicals, and fertilizers. And although natural gas lately has become a frequent fuel of choice for the generation of electric power, the lack of a transportation and distribution infrastructure for natural gas has impeded its greater use.

Natural gas is primarily a fuel or a raw material. Its use as a fuel is familiar in most developed countries. In developing countries that decide to exploit domestic gas reserves, electric power generation is frequently the first large-scale application of this resource. Natural gas also is used in conversions and retrofitting of conventional boilers, as add-on generating capacity (especially for cofiring applications), and as afterburners for stack-gas cleanup. Where gas is used directly to power turbines the efficiencies are impressive. Power-only plants may sometimes operate above 50% total thermal efficiency. Combined-cycle operation gives lower but equally impressive efficiencies.

In recent years, natural gas has also assumed a new identity in developing countries—as a major chemical feedstock used in place of naphtha or fuel oil to manufacture a variety of chemical intermediates. The most notable examples of natural-gas-derived chemicals include carbon blacks, hydrogen, synthesis gas, methanol, ammonia, urea, and other nitrogen fertilizers.

The carbon blacks are made by thermal cracking. Synthesis gas and hydrogen are produced by partial oxidation and/or steam reforming. (In many developed countries, hydrogen is usually made by catalytic steam reforming rather than by partial oxidation.) Methanol is made by catalytic reduction of the carbon monoxide in synthesis gas. Ammonia is made by catalytic conversion of synthesis gas, and urea by the reaction of ammonia and carbon dioxide to form an intermediate ammonium carbamate that is subsequently dehydrated to produce the urea.

Liquids associated with natural gas are separated in wellhead gas processing plants. These liquids are mostly C_2 to C_4 hydrocarbons and can be used as sources for ethylene, propylene, and butylenes, which may be converted further to plastics and fuel additives such as methyl *tert*-butyl ether. Olefin yields from associated liquids are usually higher than the corresponding yields from steam cracking of naphthas and gas oils.

Klass cites the convenience of natural gas as an advantage in its use in steel and foundry applications. Except in blast furnaces, where coke is required as a chemical reductant, natural gas can often be substituted for coal and coke. And in metallurgical heat-

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for heating homes and offices, because of the year-round warm climate. Use of air-conditioning, on the other hand, is expected to grow. The only household use of gas is for cooking, but this demand may remain satisfied by the use of liquefied petroleum gas, kerosene, and charcoal, depending on the income level of the consumer.

Nevertheless, however welcome rapid exploitation of natural gas might be economically, from an environmental point of view, it may be a mixed blessing. Some concerns in this regard were voiced at the Kuala Lumpur conference by Hirofumi Kataoka, executive vice president of Tokyo Gas Co.

Kataoka observes that although natural gas may be easier to live with than coal or oil, the real problem lies in consumption of fossil fuels in general. He repeats the litany of problems that have become familiar: global warming, depletion of tropical forests, ozone layer depletion, acid rain, desert expansion, marine contamination, extinction of species, transport of toxic wastes, and the growth of environmental pollution in developing countries.

From the viewpoint of the energy industry, Kataoka says, the most pressing problems are global warming, ozone layer depletion, acid rain, and environmental pollution in developing countries. These are the direct result of human activity in using energy to achieve rapid economic growth. Though pollution sources may be local, they have global effects and can last for generations.

The chemical and physical mechanisms at work in the environment are now well understood. But, Kataoka says, "if we wait until everything is scientifically understood, it may be too late." Ways must be found to minimize the impact of economic growth on the environment. If it isn't done, he says, the world may face dire consequences after 2000.

One of the nagging questions about natural gas is its future availability. Kataoka believes there will be sufficient gas available in the future. Known gas reserves are roughly equivalent to about 80% of known oil reserves, and the reserves-to-production ratio is higher than for oil. Prospects are particularly good in Asia. A major problem will be financing massive transportation and distribution systems.

To best use natural gas, Kataoka points out, a new comtreating applications, where electrical heating is used primarily, natural gas is making some inroads.

In nearly every case where it is used, natural gas provides environmental benefits. In nonferrous metals industries, for example, a range of gas-fired equipment is being used for such things as processing of bauxite and in kiln operations.

In most of the developing countries, use of natural gas in space heating is minor, usually because climates are warm. However, there is a growing demand for air-conditioning in such nations. Where use of natural gas is increasing, it is often at the expense of oil's use.

Consumption of natural gas as a chemical feedstock has risen from less than 66,000 barrels of oil equivalent (BOE; 1 BOE = 5.8 million Btu) in Africa in 1975 to about 30 million BOE in 1988. Most of this increase has been because of investment in gas-fired equipment in Libya, which accounts for 67% of Africa's gas-based chemical production. A similar, if less pronounced, trend has been noted in Algeria, Egypt, and Tunisia.

In Latin America, use of natural gas as a chemical feedstock has been growing since the early 1970s. About 17% of Latin America's chemical feedstocks are natural gas. Most of that is consumed in Mexico, where the chemical industry is the second greatest consumer of natural gas after the energy sector. Natural gas is also a major feedstock in Venezuela, Trinidad and Tobago, Colombia, and Chile.

Natural gas feedstocks in Asia have risen to about 79 million BOE in the past 15 years. The chemical industry is now the largest consumer of the gas and accounts for 30% of all regional gas consumption.

In the Middle East, gas consumption in chemical plants has been about 42 million BOE, or about 10% of total gas consumption. Most is used for generating electric power and for other industrial fuel uses. Iran, the largest consumer of natural gas in the Middle East, uses none as chemical feedstock.

As far as defining trends is concerned, Klass observes, a key factor seems to be the ratio of gas reserves to production. Where high, there is a good chance that developing nations will be able to industrialize rapidly.

Use of natural gas in developing countries varies

Country	Natural gas use, quads[a]	Total energy use, quads	Natural gas		BOE[c] per capita
			% of total	R/P[b]	
Algeria	0.70	1.64	42.7%	72	4.48
Argentina	0.81	1.71	47.3	33	9.28
Brazil	0.11	3.27	3.4	36	3.82
China	0.52	24.79	2.1	68	3.88
Egypt	0.25	1.06	23.6	52	3.58
Hungary	0.42	1.07	39.3	—	17.6
India	0.32	7.14	4.5	57	1.47
Indonesia	0.49	1.38	35.5	66	1.31
Iran	0.73	2.27	32.2	703	7.29
Malaysia	0.30	0.67	44.8	100	6.60
Mexico	0.96	4.07	23.6	55	8.09
Nigeria	0.14	0.56	25.0	652	0.92
Pakistan	0.46	0.88	52.2	43	1.28
Poland	0.50	4.81	10.4	—	21.7
Thailand	0.19	0.97	19.6	28	3.05
Venezuela	0.63	1.51	41.7	123	13.5

a 1 quad = 10^{15} Btu. **b** R/P = reserve-to-production ratio (proved reserves divided by production). **c** BOE (barrel of oil equivalent) = 5.8×10^6 Btu. **Source:** Institute of Gas Technology

mitment to research and development, especially into ways to reduce emissions of sulfur and nitrogen oxides and carbon dioxide, will need to be made. Also, cogeneration should be promoted, and natural-gas-powered vehicles should be developed. The transfer of technology will require more international cooperation than now exists, he says, and developed countries must lead the way.

But Kataoka says he is not optimistic about the future. "Gas doesn't really offer us a solution to our problems," he observes. "It does offer an alternative problem that may be less onerous to solve."

The growing dependence of Japan on natural gas was underscored at the conference by K. Ukeda, executive vice president of Osaka Gas Co. He points out that total Japanese imports of LNG will reach 10 million metric tons by 1995. Like other Asian countries, Japan views the greater use of natural gas as a way to decrease its dependence on imported oil.

Ukeda also foresees expansion of natural gas use throughout Asia, leading to new chemical industries, particularly for fertilizer, methanol, and olefins. And he notes growing interest in natural gas fuel cells to generate electric power.

Malaysia is not the only Asian country to react to the oil pricing crises of the 1970s. Since 1979, the South Korean government has also diversified its energy resources as much as possible to provide stability against future vagaries in crude-oil pricing. The first response, like that of Japan's, was to import LNG, preferably from Asian sources. This drastically reduced the use of briquettes for home heating and cooking and, in the process, reduced local pollution levels.

According to Kwang-Jin Kim, deputy general manager of the project development department for Korea Gas Corp., Seoul is the main consuming area for LNG and has constructed major LNG facilities. LNG has all but replaced town gas, a mixture of coal gas and carbureted water gas, that was formerly supplied by Korea Gas.

Kim says in the near future, Korean demand for energy is expected to increase at an annual rate of 4.6%, and the demand for natural gas will be even higher at 10.4%. In the

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CHEMICAL & ENGINEERING NEWS

C&EN

AUGUST 10, 1992

MODEST EARNINGS INCREASES CONTINUE FOR MOST CHEMICAL FIRMS PAGE 8

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COMPUTERS IN CHEMISTRY

3-D searching and
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CHEMICAL & ENGINEERING NEWS

C&EN

AUGUST 10, 1992

NEWS OF THE WEEK

- Big Science has scored two major wins in Congress: The Senate has voted to continue support of the Superconducting Super Collider, and the House rejected attempts to kill funding for space station *Freedom*. Page 3
- U.S. and Russia have signed an agreement under which the U.S. will help finance Russia's destruction of its chemical weapons stockpile. Page 4
- In aftermath of the Earth Summit, EPA Administrator Reilly has both blasted the Administration for lack of support at the meeting and praised new initiatives by the U.S. to carry out promises made at Rio. Page 4
- ICI's proposal to split into two separate companies—ICI and ICI Bioscience—comes as no surprise, is expected to be implemented early next year. Page 5
- Monsanto plans to sell its Fisher Controls subsidiary to Emerson Electric, probably because of Fisher's lackluster earnings history and poor fit with the rest of Monsanto's businesses. Page 5

COVER: Upjohn's Grow program uses de novo design to generate potential enzyme inhibitors. Photo by Upjohn's Joseph B. Moon

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CENEAR 70 (32) 1–48
ISSN 0009-2347

BUSINESS

Earnings rose for all but a few major chemical companies in the second quarter, marking the best quarter for the chemical industry in three years. **Page 8**

GOVERNMENT

Challenges facing research universities in the areas of educating and training scientists and relating to government are being scrutinized this summer by a federal panel. **Page 14**

National Academy of Sciences has requested the resignation of Russian mathematician, Igor R. Shafarevich, condemning him for anti-Semitic writings and hiring practices. **Page 15**

EDUCATION

Last month's International Chemistry Olympiad was a rousing success considering all of the complexities, especially the logistics involved in running two different schedules concurrently. **Page 27**

ACS NEWS

Mass terminations of chemists are continuing—investigations of six such firings have been completed by the Committee on Professional Relations, and a number of other incidents are being looked into. **Page 32**

Official reports of actions taken by board standing committees at June meeting of ACS Board. **Page 33**

SCIENCE/ TECHNOLOGY

New techniques for handling 3-D chemical information give scientists greater ability to understand, predict, and design biological activity. Page 18

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
Robert H. Marks, Director, Publications Division

PUBLISHING BOARD: Ned D. Heindel *(Chairman); Board of Directors Chairman:* Joseph A. Dixon; *President:* Ernest L. Eliel; Richard L. Deming; Judith C. Giordan, William P. Jencks, and Gary J. Long

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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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(For list of offices see page 47)
Office of Ombudsman: (800) ACS-5558, No. 8–5
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LETTERS

CHEMICAL SAFETY

Mercury vapor release during Kjeldahl distillation

While cleaning a macro-Kjeldahl distillation unit, after years of Kjeldahl and ammonia distillations, at least 20 mL of mercury metal was found in the condensation tubes. Apparently, the mercury had collected above smaller plastic tubes inserted into the bottoms of the glass tubes.

The Environmental Protection Agency approved procedure, which appears in recent editions of "Standard Methods," and which includes use of mercuric sulfate as the preferred and nearly sole catalyst available, was followed. But how did the mercury metal arise? It appears that some of the mercury(II) was reduced by a sulfur species in the sodium hydroxide-sodium thiosulfate solution during the distillation. No warning of this hazard is given in the most recent "Standard Methods" (17th edition), the EPA "Methods for Chemical Analysis of Water and Wastes" (1983), or in any other literature we have seen.

What was even more insidious than the mercury itself, was the way it built up in the condenser tubes, without giving away its presence by visible drops of mercury, over years of titrations. Once in a while, the walls of boric acid-containing receiving flask did show a trace of a black substance, which may have been finely divided mercury or mercuric sulfide that had foamed over.

Because of the release of mercury vapor into the air allowed by this process, this distillation, especially if not done in a hood, presents a hazard to all laboratory personnel. We recommend using the copper catalyst that the 17th edition of "Standard Methods" allows [if organic nitrogen recovery is close to that obtained by the mercury(II) catalyst], or, if it is absolutely necessary, to use mercury(II), to set the apparatus in the hood. We hope that EPA soon sees fit to approve a mercury-free procedure to be published in a future *Federal Register*.

David Lewis
Chemist
City of Lompoc
Lompoc, Calif.

Alfred Bader

I read with great sadness the article on Alfred Bader (C&EN, April 6, page 39). Although I was aware of some of the developments within Sigma-Aldrich, I feel very strongly that they have made a foolish mistake by removing their strongest supporter from the board.

There are many things I could say about Bader, but for the purposes of this letter I restrict myself to two—one professional and one personal. Through his energy and interest in chemistry, he has established a world network of personal contacts who have appreciated his visits and help. Through these contacts, he established Aldrich as a household name, but much more importantly, he has advanced science by making available a massive range of research materials, many of which he personally championed to the Aldrich catalog through his visits to the research groups involved with the initial discoveries. The ready availability of these compounds has stimulated new areas of research worldwide.

On the personal side, I have found Bader to be one of the most honest, kindhearted, and pleasant individuals whom I have had the pleasure of knowing as a professional colleague and friend. I am disappointed that Sigma-Aldrich is making the decision it is. It cannot be wise for Sigma-Aldrich, and it certainly is not in our best interest either. If they wish to remove members from their executive board, I could suggest others who I believe should step down rather than the man who has given his life for the good of the company.

Steven V. Ley, FRS
Professor of Organic Chemistry
Head of Department
Imperial College of Science, Technology & Medicine, London

Correction

- June 29, page 80: The allotments for all ACS local sections in 1993 should total $1,039,139, instead of the reported figure of $1,038,553.

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Chemical Industry Enjoys Best Financial Quarter in Three Years

William J. Storck,
C&EN Northeast News Bureau

Second-quarter 1992 may be remembered as the watershed for the chemical industry because it can be argued that in that quarter, the long string of earnings declines virtually ended.

Combined earnings at the 30 chemical companies regularly surveyed by C&EN did show a decline from the same period last year—but of only 0.4%. This is by far the smallest drop since the year-to-year declines in quarterly results began in third-quarter 1989.

In addition, as in the past few quarters, the companies showing earnings declines were vastly outnumbered by those showing gains. In the second quarter, just six of the 30 chemical companies had lower earnings than a year earlier; the remaining 24 all posted higher earnings.

It probably is true that the 30 companies' earnings from operations, excluding significant nonrecurring and extraordinary charges (the way C&EN reports earnings, when possible), were unchanged from a year ago. Morton International had a $12 million pretax charge in the quarter that the company did not report on an after-tax basis, rendering it impossible to factor out of the results. If this could have been taken out, it probably would have eliminated the $6 million decline in combined earnings for the 30 companies between the second quarter of last year and the same period in 1992.

Monsanto's drop represented by far the largest dollar decrease—$134 million. If Monsanto's results alone were not included in the group tally, overall earnings for the other 29 companies would have been up 13% for the quarter. This is reminiscent of the first quarter when a big decline at Dow Chemi-

Chemical industry leaders for second quarter . . .

Sales				Earnings[a]			Profitability		
Rank 1992		$ Millions	Rank 1991		$ Millions	Rank 1991		Earnings as % of sales	Rank 1991
1	Dow Chemical	$4859.0	1	Dow Chemical	$200.0	2	International Flavors	18.8%	1
2	Monsanto	2280.0	2	American Cyanamid	147.5	3	Great Lakes Chemical	15.4	3
3	American Cyanamid	1477.3	3	Monsanto	139.0	1	Loctite	13.2	2
4	W. R. Grace	1370.8	4	Rohm & Haas	76.4	6	Imcera	11.8	12
5	Union Carbide	1257.0	5	Arco Chemical	74.0	14	Betz Laboratories	11.6	4
6	Air Products	824.7	8	Air Products	68.4	5	Nalco Chemical	10.7	6
7	Rohm & Haas	783.3	6	W. R. Grace	64.1	4	American Cyanamid	10.0	7
8	Arco Chemical	769.0	9	Great Lakes Chemical	58.8	9	Rohm & Haas	9.8	15
9	Hercules	713.2	7	International Flavors	55.4	8	Arco Chemical	9.6	19
10	Ethyl	662.0	10	Imcera	55.1	13	Crompton & Knowles	9.6	8

. . . and for first six months of 1992

Sales				Earnings[a]			Profitability		
Rank 1992		$ Millions	Rank 1991		$ Millions	Rank 1991		Earnings as % of sales	Rank 1991
1	Dow Chemical	$9498.0	1	Dow Chemical	$368.0	1	International Flavors	18.3%	1
2	Monsanto	4468.0	2	Monsanto	300.0	2	Great Lakes Chemical	15.4	3
3	American Cyanamid	2855.9	4	American Cyanamid	262.3	3	Loctite	13.3	2
4	W. R. Grace	2603.5	3	Arco Chemical	144.0	15	Betz Laboratories	11.5	4
5	Union Carbide	2444.0	5	Air Products	141.7	4	Nalco Chemical	10.4	5
6	Air Products	1618.0	7	Rohm & Haas	135.7	8	Lubrizol	10.1	8
7	Arco Chemical	1531.0	9	Ethyl	115.8	5	Imcera	9.7	14
8	Rohm & Haas	1497.7	8	Great Lakes Chemical	111.8	10	Arco Chemical	9.4	24
9	Hercules	1457.3	6	International Flavors	106.1	6	American Cyanamid	9.2	7
10	Ethyl	1340.0	11	W. R. Grace	89.1	7	Crompton & Knowles	9.2	9

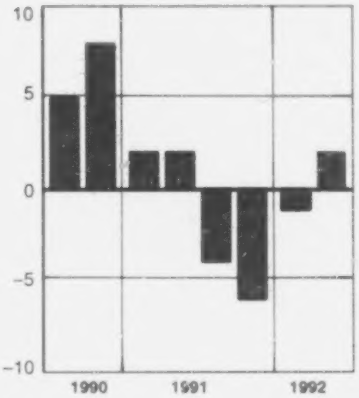
Note: Based on 30 chemical companies listed on page 10 [a] After taxes

Chemical industry 1992 second-quarter results

- **Sales rose 2%**
- **Earnings were flat**
- **Profit margin was 5.9%**
- **Production rose 5.7%**
- **Prices were flat**

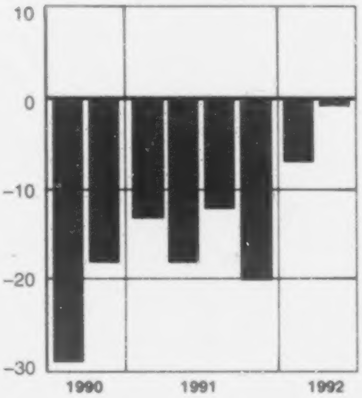
Sales

% change from year-earlier quarter



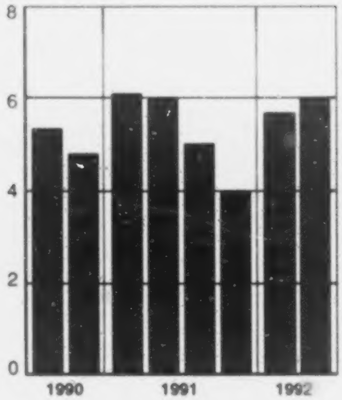
Earnings

% change from year-earlier quarter



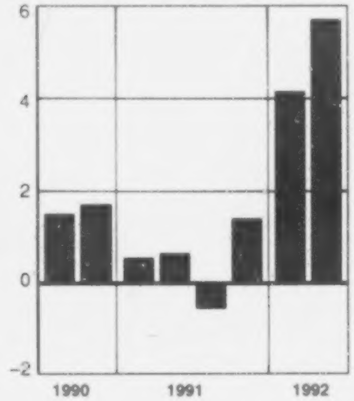
Profit margins

After-tax earnings as % of sales



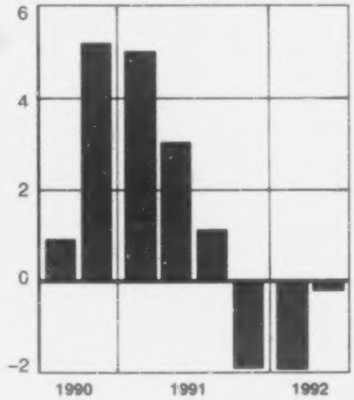
Production

% change from year-earlier quarter



Prices

% change from year-earlier quarter



Note: All sales, earnings, and profit margin data are based on 30 chemical companies listed on page 10

cal brought the total group's earnings change to a 7% decrease from an otherwise 10% increase without Dow included.

If the second quarter does finally signal the end of the declines for the chemical industry, then chemical companies have a long way to go to make up the lost ground. In the past three years the recession has taken a huge toll on earnings: just-tallied second-quarter results are still 39%, or $780 million, less than in second-quarter 1989. And, on a 12-month basis through June, earnings for the 30 companies surveyed are about $3 billion below those in 1988, the last full year of expansion.

Other data also signal that the chemical recession may be coming to a close. For instance, prices of chemicals and allied products in the second quarter were essentially unchanged from 1991's second quarter, according to data from the Department of Labor. If it were not for the unusual runup in prices during the first part of 1991 because of the Gulf War and its aftermath, second-quarter price data this year also would have shown an improvement.

Production is increasing, with chemical output in the second quarter of this year up almost 6% over the comparable period in 1991. This is the biggest year-to-year change in more than three years, according to government data. The caveat is that for industrial chemicals, the main staple of the industry, production and prices are lagging those for all chemical products. However, this is a normal trend, with specialty chemicals, including pharmaceuticals, leading the way out of recession.

Linked to production, plant capacity utilization was about 80% in the second quarter, according to government estimates, its highest level during the recession. The increase in capacity use should mean that companies' profitability will increase, as plants that are operating at better rates run more efficiently and productively, increasing

All but six companies posted earnings gains in second quarter

	SECOND-QUARTER 1992						FIRST-HALF 1992			
	Sales	Earnings[a]	Change from 1991		Profit margin[b]		Sales	Earnings[a]	Change from 1991	
	($ millions)		Sales	Earnings	1992	1991	($ millions)		Sales	Earnings
Air Products	$ 824.7	$ 68.4	16%	20%	8.3%	8.0%	$ 1,618.0	$ 141.7	10%	15%
American Cyanamid	1,477.3	147.5	4	12	10.0	9.3	2,855.9	262.3	4	11
Arco Chemical	769.0	74.0	9	124	9.6	4.7	1,531.0	144.0	11	235
Betz Laboratories	175.9	20.4	6	8	11.6	11.3	351.5	40.5	7	9
Cabot	371.0	16.4	7	155	4.4	1.9	788.9	38.4	4	75
Crompton & Knowles	134.6	12.9	13	20	9.6	9.0	248.3	22.7	10	21
Dow Chemical	4,859.0	200.0	1	–14	4.1	4.9	9,498.0	368.0	–3	–38
Ethyl	662.0	52.6	4	5	7.9	7.9	1,340.0	115.8	4	12
First Mississippi	130.1	1.1	–14	108	0.9	0.4	252.9	3.4	–11	46
H. B. Fuller	234.6	10.1	8	42	4.3	3.3	453.4	16.2	8	50
Georgia Gulf	193.0	13.5	–10	–19	7.0	7.8	382.6	26.5	–15	–22
B. F. Goodrich	657.3	13.1	3	58	2.0	1.3	1,262.6	13.2	4	144
W. R. Grace	1,370.8	64.1	–2	5	4.7	4.4	2,603.5	89.1	–5	–6
Great Lakes Chemical	381.6	58.8	10	47	15.4	11.5	726.1	111.8	9	42
Hercules	713.2	43.2	–3	18	6.1	5.0	1,457.3	80.1	–3	16
IMC Fertilizer	279.7	7.6	–8	–58	2.7	6.0	565.3	27.9	–4	–24
Imcera	467.9	55.1	3	62	11.8	7.5	901.4	87.7	5	43
International Flavors	295.6	55.4	11	14	18.8	18.4	579.7	106.1	8	11
Loctite	154.2	20.4	9	8	13.2	13.4	301.6	40.0	8	16
Lubrizol	414.7	39.4	12	43	9.5	7.5	829.6	83.5	12	33
Monsanto	2,280.0	139.0	–8	–49	6.1	11.0	4,468.0	300.0	–5	–32
Morton International	505.0	34.4	9	1	6.8	7.3	1,060.5	75.6	8	1
Nalco Chemical	340.3	36.4	7	10	10.7	10.4	666.8	69.4	14	8
Olin	632.9	20.8	11	1	3.3	3.6	1,247.1	44.4	10	6
Petrolite	79.6	4.4	–4	16	5.5	4.5	159.6	8.7	–1	32
Quantum Chemical	542.7	–41.7	–7	def	def	def	1,174.0	–53.8	–11	def
Rohm & Haas	783.3	76.4	4	45	9.8	7.0	1,497.7	135.7	5	44
Stepan	113.9	4.1	9	52	3.5	2.6	221.3	8.2	7	60
Union Carbide	1,257.0	26.0	4	–28	2.1	3.0	2,444.0	70.0	–4	–24
Witco	426.9	18.0	1	12	4.2	3.8	847.3	36.9	3	13
TOTAL[c]	$21,528.4	$1291.9	2%	0%	6.0%	6.1%	$42,333.8	$2514.1	1%	–3%

a After tax earnings from continuing operations, excluding significant nonrecurring and extraordinary items. b After tax earnings as a percentage of sales. c Includes nonrecurring items.

operating margins. And as capacity utilization improves, chemical companies will be able to increase prices, giving themselves greater earnings leverage. However, operating rates probably will have to rise to the high-80 to low-90% levels before there are any substantial increases in prices above increases in raw material costs.

Driving the recovery in production is some upward movement in major end-use markets. Housing starts are still moving upward, although the commercial real estate market continues in dire straits. The increase in housing starts affects fibers, plastics, and other home-oriented downstream chemical products.

The number of autos produced domestically, although still languishing, is forecast by some economists to be up about 5% this year over 1991. This will help mainly the plastics and paint industries, but also will boost demand for fibers.

For the second quarter, overall, however, these situations did not develop fast enough as mirrored in the results of the 30 companies. Combined sales of the companies totaled $21.5 billion, a modest 2% increase over the same period the year before. Earnings totaled $1.29 billion, essentially the same as in second-quarter 1991. The result was a slight decline in profit margin—earnings as a percent of sales—with the average for the group falling to 6.0% in the second quarter from 6.1% in last year's second quarter.

Chemical companies (defined by C&EN as having half or more of sales contributed by chemicals) can take heart in once again outperforming the oil industry. For 11 oil companies surveyed by C&EN, earnings fell 10% to $2.35 billion on a 3% sales increase to $84.4 billion. Interestingly, however, chemical earnings for five of the oil companies reporting—Amoco, Exxon, Chevron, Occidental Petroleum, and Texaco—increased an average 5% over second-quarter 1991.

However, pharmaceutical companies as well as diversified companies that produce chemicals both handily outperformed chemical companies. The 11 diversified firms surveyed posted a combined 21% increase in earnings to almost $1.77 billion on a narrow 1% sales increase to about $30 billion. And

FIRST-HALF 1992		12-MONTH RUNNING DATA			
Profit margin[b]		Change from 1991		Profit margin[b]	
1992	1991	Sales	Earnings	1991	1990
8.8%	8.4%	4%	10%	8.5%	8.0%
9.2	8.7	11	15	7.0	6.8
9.4	3.1	3	–34	5.5	8.6
11.5	11.2	10	13	11.4	11.1
4.9	2.9	–11	–19	3.3	3.7
9.2	8.4	14	20	8.2	7.8
3.9	6.1	–7	–40	4.2	6.5
8.6	8.0	2	–5	8.1	8.6
1.4	0.8	3	82	1.8	1.0
3.6	2.6	7	22	3.5	3.0
6.9	7.5	–13	–38	7.2	10.2
1.0	0.4	3	–85	0.5	3.4
3.4	3.4	–11	3	3.5	3.0
15.4	11.8	17	18	12.8	12.7
5.5	4.6	–9	22	4.9	3.6
4.9	6.2	–5	–11	7.4	8.0
9.7	7.1	7	24	6.6	5.7
18.3	17.9	4	6	16.7	16.4
13.3	12.4	2	12	13.3	12.0
10.1	8.5	3	–4	8.8	9.5
6.7	9.3	–1	24	7.0	5.6
7.1	7.6	7	7	7.2	7.2
10.4	11.0	12	4	10.4	11.3
3.6	3.7	–7	–4	3.0	2.9
5.5	4.1	7	32	5.0	4.0
def	def	–11	def	def	1.3
9.1	6.6	0	–7	6.5	6.9
3.7	2.5	6	6	3.4	3.4
2.9	3.6	–10	–77	1.0	3.7
4.4	4.0	1	16	4.6	4.0
5.9%	6.2%	2%	–15%	5.5%	6.6%

def = deficit

10 pharmaceutical producers surveyed registered a 10% earnings gain to nearly $2.95 billion on a 9% sales increase to $17.8 billion.

For the first six months of 1992, combined earnings for the group of chemical companies slipped 3% from first-half 1991 to about $2.51 billion on a 1% sales increase to $42.3 billion. Profit margin for the group averaged 5.9%, down from 6.2% in the first half of last year.

Even with Monsanto's major negative effect on chemical second-quarter results, chemical operations at the company suffered relatively little. According to the company, operating income for its chemical group—eliminating the effects of a 1991 reorganization and of a 1992 lawsuit settlement—declined only 3% from the same period a year ago. Most of the damage at Monsanto came in its pharmaceutical and NutraSweet operations, with agricultural chemicals also contributing.

The other five companies that reported earnings declines in the quarter were IMC Fertilizer, down 58% to $7.6 million; Union Carbide, down 28% to $26 million; Georgia Gulf, down 19% to $13.5 million; Dow Chemical, off 14% to $200 million; and Quantum Chemical, where the red ink deepened to a loss of $41.7 million from a loss from operations of $33.7 million in second-quarter 1991.

Three of the chemical companies surveyed more than doubled earnings from operations in the second quarter—First Mississippi, Arco Chemical, and Cabot.

First Mississippi increased earnings 108% to $1.1 million as sales fell 14% to $130 million. The company notes that its earnings increase came from fertilizers, gold, oil, and gas.

Arco Chemical boosted earnings from operations 124% to $74 million—the largest earnings gain of the 30 companies in terms of dollar volume—and sales rose 9% to $769 million. Alan R. Hirsig, president and chief executive officer, says, "Lower year-to-year feedstock costs contributed to the significant increase in earnings from operations, as did the growth in sales volumes, particularly in our Americas region. Recent volume trends are stable and are definitely at higher levels than last year. However, the strength of the economic recovery is still of concern."

At Cabot, earnings soared 155% to $16.4 million on a 7% sales increase to $371 million. Company chairman Samuel W. Bodman says that most of the gain came from better management of costs. In terms of the economy, he says, "For most of this year we have benefited from some improvement in the business climate, but the improvement has been sporadic and unpredictable—up some months, down others. Convincing evidence of meaningful and sustainable improvement in the global economy is still absent."

Another company still worried about the economy is Dow Chemical. Its executive vice president and chief financial officer Enrique C. Falla says: "Our latest results are disappointing even though they show an improvement over the first quarter of the year, which could very well be our trough quarter. Earnings are still unfavorable when making year-to-year comparisons, and we do not expect to exceed 1991 results until sometime in the second half of this year."

W. R. Grace, although expecting to continue increased earnings in the second half, seems slightly unsure about the strength of the recovery. Chairman J. Peter Grace says, "Our latest estimates suggest each of our core busi-

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 22 oil and diversified companies, each with more than $200 million in annual chemical sales, plus 10 pharmaceutical companies.

To be included in the table of basic chemical producers, a company must have at least 50% of its sales in chemicals. That is why Du Pont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, and agricultural chemicals and specialty derivatives.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

Diversified companies showed better earnings performance than oil or drug companies

	FIRST-QUARTER 1992						FIRST-HALF 1992					
	Sales	Earnings[a]	Change from 1991		Profit margin[b]		Sales	Earnings[a]	Change from 1991		Profit margin[b]	
	($ millions)		Sales	Earnings	1992	1991	($ millions)		Sales	Earnings	1992	1991
OIL AND GAS COMPANIES												
Amoco	$ 7,370.0	$ 237.0	9%	–23%	3.2%	4.5%	$ 13,759.0	$ 423.0	–2%	–42%	3.1%	5.2%
Ashland	2,628.7	20.6	10	–69	0.8	2.8	4,881.6	11.5	7	–88	0.2	2.1
Chevron	10,600.0	389.0	9	47	3.7	2.7	20,300.0	606.0	–1	–28	3.0	4.1
Exxon	27,759.0	955.0	2	–15	3.4	4.1	55,673.0	2305.0	–4	–32	4.1	5.8
Kerr-McGee	876.2	30.3	12	194	3.5	1.3	1,658.9	38.9	6	–3	2.3	2.5
Mobil	15,189.0	255.0	5	–36	1.7	2.8	30,340.0	468.0	–2	–58	1.5	3.6
Occidental Petroleum	2,176.0	43.0	–9	–34	2.0	2.7	4,330.0	64.0	–16	–55	1.5	2.8
Phillips Petroleum	3,090.0	104.0	–5	215	3.4	1.0	5,849.0	16.0	–14	–93	0.3	3.2
Sun Co.	2,690.0	6.0	–11	–89	0.2	1.8	5,220.0	–7.0	–13	def	def	1.7
Texaco	9,400.0	245.0	4	–9	2.6	3.0	17,960.0	445.0	–7	–35	2.5	3.6
Unocal	2,670.0	66.0	–2	1220	2.5	0.2	5,090.0	82.0	–6	3	1.6	1.5
TOTAL	$84,448.9	$2350.9	3%	–10%	2.8%	3.2%	$165,061.5	$4,452.4	–4%	–40%	2.7%	4.3%
DIVERSIFIED MANUFACTURERS												
Allied-Signal	$ 3,075.0	$ 145.0	1%	20%	4.7%	4.0%	$ 6,054.0	$ 272.0	2%	48%	4.5%	3.1%
Du Pont	9,774.0	573.0	–1	14	5.9	5.1	18,959.0	1,056.0	–3	–3	5.6	5.6
Eastman Kodak	5,190.0	361.0	4	1	7.0	7.2	9,600.0	506.0	2	–5	5.3	5.7
Engelhard	637.2	26.9	–2	17	4.2	3.5	1,267.1	50.7	–1	15	4.0	3.4
FMC	1,061.1	65.4	1	5	6.2	6.0	1,995.0	120.1	4	19	6.0	5.3
Ferro Corp.	291.9	14.7	8	48	5.0	3.7	564.6	27.7	6	116	4.9	2.4
3M	3,504.0	322.0	5	8	9.2	8.9	6,910.0	610.0	3	2	8.8	8.9
NL Industries	217.2	17.6	–8	def	8.1	def	442.3	–21.8	–4	def	def	def
PPG Industries	1,513.1	106.7	2	35	7.1	5.4	2,959.0	185.5	4	84	6.3	3.5
Tenneco	3,435.0	105.0	0	def	3.1	def	6,645.0	140.0	–1	def	2.1	def
Vulcan Materials	284.2	30.2	7	17	10.6	9.7	494.8	34.9	7	47	7.0	5.1
TOTAL	$28,982.7	$1767.5	1%	21%	6.1%	5.1%	$ 55,891.6	$2,981.1	0%	12%	5.3%	4.8%
PHARMACEUTICAL COMPANIES												
Abbott Laboratories	$ 1,908.7	$ 317.1	13%	–18%	16.6%	15.9%	$ 3,786.6	$ 611.3	13%	17%	16.1%	15.7%
American Home Products	1,756.2	296.1	8	12	16.9	16.4	3,754.7	702.4	11	14	18.7	18.3
Baxter International	2,421.0	156.0	10	11	6.4	6.4	4,717.0	287.0	9	14	6.1	5.8
Bristol-Myers Squibb	2,880.4	488.0	5	0	16.9	17.9	5,663.8	1,035.5	4	5	18.3	18.0
Eli Lilly	1,478.3	338.2	7	7	22.9	23.1	3,035.4	780.8	8	11	25.7	25.1
Merck	2,373.7	653.4	12	18	27.5	26.2	4,597.0	1,222.1	10	18	26.6	24.9
Pfizer	1,694.2	203.8	4	14	12.0	11.0	3,455.5	498.9	4	12	14.4	13.4
Schering-Plough	1,019.6	184.9	12	10	18.1	18.3	2,041.5	378.2	10	11	18.5	18.3
Upjohn	883.6	129.9	3	2	14.7	14.8	1,755.4	273.6	6	5	15.6	15.7
Warner Lambert	1,373.3	177.8	11	15	12.9	12.5	2,684.9	341.5	9	16	12.7	12.0
TOTAL	$17,789.0	$2945.2	9%	10%	16.6%	16.3%	$ 35,491.8	$6,131.3	8%	12%	17.3%	16.7%

[a] After-tax earnings from continuing operations, excluding significant nonrecurring and extraordinary items. [b] After-tax earnings as a percentage of sales. **def** = deficit.

nesses should exceed results from last year's second half. On this basis, reaching our full-year objective of at least 10% growth is attainable, but it will be a challenge, particularly if the European economy does not recover from its present low level."

No matter what happens in Europe or elsewhere, most chemical executives believe, and probably rightly so, that the recovery is going to be a slow, and perhaps sporadic, affair. Bodman's comments about the month-to-month differences in the economy will, for the short term, at least, be right on the mark.

For instance, the government reported last week the index of leading economic indicators in June fell slightly after rising for five straight months. Analysts are taking this as a sign that economic activity will be slow, at least through September, and may need a further spur from the government. If they are right, look for chemical earnings in the third quarter, and perhaps for the rest of the year, to be up from year-earlier levels—but don't look for the big double-digit increases seen before the recession. ☐

Firings of Chemical Professionals Continue To Proliferate

Mass firings of chemists are apparently continuing to pervade chemical and related industries. The latest report by the American Chemical Society's Committee on Professional Relations (CPR) presents completed investigations of six such mass terminations, indicates that five more are under investigation, and states that 22 other, so far unverified, incidents are being looked into.

The new report is the 34th in a series dating back to 1974. As with earlier reports, it compares the compliance performance of the employers involved with five standards spelled out in ACS's Professional Employment Guidelines (PEG).

These guidelines are concerned with advance notice, severance pay, assistance after termination, length of employee service, and employee protection after termination. Average compliance by the six firms involved in the latest report was 47%. This was slightly better than an average of 41% for the previous 33 reports.

The six terminations for which the investigations are complete involved the loss of a total of about 60 chemical jobs. The biggest cut was 15 at Unocal. The other organizations involved were BASF, General Tire, NutraSweet, Revlon Science Institute, and Westinghouse. None of these employers provided CPR with data on these terminations. All data for the investigations came from the terminees themselves. Of those identified individually as terminees, 75% responded to questionnaires from CPR.

CPR defines a mass termination as a situation in which three or more chemists or chemical engineers are terminated by the same employer within a six-month period for reasons other than continuing evidence of previously documented inadequate performance, completion of a contract, or cause.

Compliance with the PEG standards has improved modestly over the years.

Employer compliance with ACS employment guidelines

These employers provided no information	Approximate number of employees separated	Advance notice	Severance pay	Assistance	Employee service	Protection plans
BASF (Wyandotte, Mich., Kearny, N.J.)	5	■	☐	☐	■	▨
General Tire (Akron, Ohio)	11	▨	■	☐	■	▨
NutraSweet (Mt. Prospect, Ill.)	10	☐	☐	☐	■	▨
Revlon Science Institute (San Diego)	11	■	☐	■	☐	▨
Unocal (Brea, Calif.)	15	☐	☐	☐	■	■
Westinghouse S&T Center (Pittsburgh)	8	☐	☐	☐	■	▨

☐ Employer met or exceeded guideline standard.

▨ Two or more individuals below guideline standard, but average experience better than "substantially below" criterion.

■ Employer was substantially below guideline standard, which is defined as follows:

- Advance notice—less than four weeks.
- Severance pay—less than two weeks per year of service.
- Assistance—no assistance rendered.
- Employee service—more than 30% of terminees had 10 or more years of service.
- Protection plans—no continuation of protection plans.

ACS Professional Employment Guidelines

- Advance notice. Four-week minimum.
- Severance pay. Minimum is two weeks per year of service. Additional notice may be given, by mutual agreement, in lieu of severance pay.
- Assistance. Efforts should be made to place terminee in another position within the organization, or terminee should be given assistance to find employment elsewhere.
- Employee service. Those with minimum of 10 years' service should not be terminated except for continued evidence of previously documented inadequate performance or cause.
- Employee protection plans. Should be extended for a minimum of one month, plus two weeks for each year of employee service, following termination, at same rate of contribution as before. Employee would have additional 31-day grace period.

For the first 17 reports, through 1983, it averaged 40%. Since then, it has averaged 43%.

The biggest change has come in meeting the standard of two weeks' pay for each year of service. For the first 17 reports, only 13% of employers complied. For the second 17, compliance was 37%. However, compliance with the standard designed to protect employees with more than 10 years of service has moved the other way. For the earlier reports, 28% of employers complied by not firing such employees. For the latter reports, compliance is down to 15%.

These trends are reflected in the latest report. Five of six employers met the severance pay standard. But five out of six terminated chemical professionals with more than 10 years of service.

Of the other standards, that for advance notice has been complied with 41% of the time for all 34 reports—three out of six in the latest report. The standard for helping terminees to find new employment was met by all but one of the employers in the latest report and by 82% of employers since 1983. The standard calling for extending employee protection plans for a period after termination has been met by 48% of employers in all 34 reports. But none did so in the latest report.

CPR requests that chemical professionals who have been fired or have taken early retirement contact the American Chemical Society, Office of Professional Services, 1155—16th St., N.W., Washington, D.C. 20036. Copies of all CPR termination reports and related C&EN stories are available, on request, from the same office.

Michael Heylin

Official Reports from the June Board Meeting

Only board standing committees met during the ACS Board's meeting in June at the society's Belmont Conference Center in Elkridge, Md. Among actions taken by the board at that meeting were confirmation of an amendment to Bylaw II, Sec. 6, governing use of Corporation Associates dues, and approval of meeting sites and dates of ACS national meetings in 1996 and 2002, recommended by the council earlier this year. Following are the committees' reports.

Reports of Standing Committees

Grants & Awards

The board of directors approved the committee's recommendations to increase the value of several awards that recognize achievement in organic chemistry. The personal stipends associated with the Arthur C. Cope Award and the Roger Adams Award will both be raised from $15,000 to $25,000. The Cope Award grant-in-aid for research will increase from $30,000 to $50,000, and the similar research grant for Arthur C. Cope Scholars will be $25,000 instead of $20,000. All of these changes will take effect with the 1993 presentations.

The committee approved 164 ACS-PRF grants totaling $5,036,160 for fundamental research and scientific education from 460 proposals. PRF grant commitments for 1992, now complete, total $14,413,529. The committee also approved an increase in membership of the PRF Advisory Board from 26 to 28, in response to growth in the number of research proposals.

John G. Verkade, *chairman*

Professional & Member Relations

The committee considered statistics on the status of employment in the chemical industry based on a staff report on career services for ACS members. Noting that current economic conditions have resulted in a higher number of requests for dues deferral from unemployed members (649 as of May 31), the committee discussed ways to ensure that member needs for career services are being met. Accordingly, it recommended that the board of directors grant a special 1992 appropriation of $25,000 to be used at the Washington national meeting to enhance career services for members, and to increase travel funds for staff to provide career services on request of local and regional groups.

In other actions, the committee recommended that the board approve a revised publication schedule for *Reaction Times*, a college science newspaper; recommended that the board refer to the divisions of Analytical Chemistry and of Physical Chemistry for consideration as cosponsoring groups a request for ACS to be a cooperating society in a spectroscopy meeting; and agreed to ask the Committee on Membership Affairs routinely to send graduate research directors at institutions granting advanced degrees a letter describing ACS activities, and encouraging the directors to share these letters with their graduate students.

Stanley Kirschner, *chairman*

Public Affairs & Public Relations

The committee was updated on activities of the Van Task Force that is investigating opportunities for ACS to become involved in chemistry "van programs" now being conducted across the U.S. It was recommended that the board of directors confirm the appointment of this task force.

The committee discussed a request to have prominent chemists featured on U.S. postal stamps, and recommended board endorsement of pursuing the concept with the U.S. Postal Service to include the science of chemistry and its practitioners on U.S. postal stamps.

Based on a report of usage statistics that was presented, the committee concluded that the Media Science Electronic Bulletin Board in the Department of Public Communications is a concept ahead of its time. The committee therefore recommended to the board of directors that it be discontinued by Sept. 1, 1992, and that its funding be redirected to other areas of public communications.

This is the third year for the ACS annual Federal Policy Agenda. Since the issues addressed normally do not change within a calendar year, the committee recommended to the board of directors that the Federal Policy Agenda be issued on a biennial basis corresponding with the beginning of each new Congress. The first biennial issue will be available in January 1993.

C. Marvin Lang, *chairman*

Nominations sought for Baekeland Award

The ACS North Jersey section is soliciting nominations for the 1993 Leo Hendrik Baekeland Award. The award, supported by the section and Union Carbide, consists of a gold medal and a $1000 honorarium. It is given in recognition of accomplishments in pure or industrial chemistry to an American chemist who will be under the age of 40 as of Jan. 1, 1993. Nominations should include a letter describing the nominee's achievements, a biography, and a list of publications. Renominations are encouraged. Submit materials by Nov. 30 to Nicholas I. Carruthers, Schering Plough Research Institute, 60 Orange St., Bloomfield, N.J. 07003. ☐

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NEWS OF THE WEEK

- The North American Free Trade Agreement, announced last week by President Bush, is being hailed by the chemical and pharmaceutical industries. **Page 6**
- Drug companies will pay user fees to enable FDA to hire new examiners and speed up drug approval, under a plan winning support from industry and Congress. **Page 6**
- Report by National Science Board panel berates declining state of industrial R&D in the U.S. **Page 7**
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COVER: Researcher works on oil additives at Texaco's R&D facility in Beacon, N.Y.

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CHEMICAL R&D

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
Robert H. Marks, Director, Publications Division

PUBLISHING BOARD: Ned D. Heindel *(Chairman); Board of Directors Chairman:* Joseph A. Dixon; *President:* Ernest L. Eliel; Richard L. Deming; Judith C. Giordan; William P. Jencks, and Gary J. Long

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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Alcohols for motor fuel

Thank you much Jim Wei for your glorious review of the first two volumes of the "Kirk-Othmer Encyclopedia of Chemical Technology" (C&EN, June 8, page 27) and for your fond anticipation of a half-dozen future articles on topics that interest you. This acknowledgment comes from all who have been, and are, a part of Kirk-Othmer.

One slight nitpick, please! You wrote that "a very important drawback of [alcohols for motor] fuels [is] lower energy per gallon, which translates to a shorter cruise range than gasoline affords before refueling." Not so. At the classic Indianapolis 500, for almost a generation, every race car has used methanol, and pit stops for fuel are anathema.

A personal survey of drivers a few classics back showed that this nuisance was washed out entirely in favor of methanol, because methanol's much greater efficiency allows smaller, lighter engines; lower running temperatures with methanol give greater dependability and longer life to the very expensive engines; and methanol allows much greater safety and many fewer and more easily extinguishable fires during wrecks. (There was a potential record number of wrecks in this year's classic, but no driver was incinerated in fires.) Methanol's oxygen gives less heat of combustion, of course, but it also eliminates knocks and the necessity for lead. Given a chance, drivers of regular cars will agree it is an excellent fuel.

Read on, Dr. Wei. We surely hope that your enthusiasm will continue, it is greatly appreciated.

Donald F. Othmer
Distinguished Professor
Polytechnic University
Brooklyn, N.Y.

A bureaucrat's-eye view

Now the silly season is in full swing, that is, a presidential election year. We bureaucrats hunker down. Your article on EPA contracting (C&EN, July 20, page 18) indicates this silly season may be sillier than usual. We don't mind, many of us. These silly seasons come and go. Things blow over. Nothing changes much. And the amazing thing is that it is all by design. This government will always continue to operate inefficiently. There isn't a lot anyone can do about it, total quality management notwithstanding, short of changing the Constitution. The framers of the Constitution are to blame. They feared a concentration of power and so devised a system of checks and balances. The result: a distribution of power among the branches and an inherently inefficient system. Oh, there have been examples of efficient government—Mussolini, the trains ran on time—but the price is too dear. Our form of government (alas, the republican form, small r, as opposed to democratic, small d, but still one that puts the power of government in the hands of the governed, limited by the Constitution) is the best system in the world. No sarcasm intended. It's the best system the world has ever known. And many countries now have it or something similar. Inefficiency and waste abound.

The silly season brings a lot of bureaucracy bashing. Candidates run against the government. Government is too big. It costs too much. It is inefficient. It's time for a change. Cut spending. Cut taxes. Reduce the deficit.

In this silly season, the Environmental Protection Agency stands apart. Top management there, instead of hunkering down and saying, "Yes yes, we will clean up our act; we will get efficient; we will wisely spend the taxpayers' dollars," has apparently opted for less efficiency. I am astounded, okay not astounded, amused maybe, to hear EPA's Christian Holmes badmouth a cultural mind-set "that views our environmental protection mission as more important than how we manage contracts." Imagine that! Somewhere in the federal government, employees seem focused on their mission and not on the red tape. But if this is amusing, what is really disturbing, dismaying even, is to learn that in Holmes' agency, one out of every 40 employees works for the inspector general. How many federal employees does it take to screw in a light bulb?

The federal bureaucracy is too big and complex for simple solutions. It is complex because of constraints imposed by Congress. (I'm not badmouthing Congress. Congress is functioning just the way the framers of the Constitution intended it to.) Politics requires the executive branch to keep the size of the bureaucracy minimal and accomplish work through contractors whenever possible, "inherent governmental functions" being, of course, excepted. The federal gov-

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Facts & Figures for CHEMICAL R&D

Mairin B. Brennan and **Janice R. Long,**
C&EN Washington

R&D spending in the U.S. is expected to rise in 1992 to $157 billion, according to estimates by the National Science Foundation. This new high represents a 4% gain over 1991, or slightly more than 1% when adjusted for inflation, and makes 1992 the first year of real growth since 1989.

Viewed in somewhat broader perspective, 1992 continues the pattern of restrained R&D spending that began in 1986. Since then, after adjusting for inflation, overall R&D spending in the U.S. has risen at an annual rate of just over 1%, well below the 5 to 9% annual growth rates of the early 1980s. Thus, although inflation-adjusted R&D spending grew 29% from 1982 to 1986, it rose a much more modest 6% from 1986 to 1992.

As it has since 1981, industry will provide more than half of the total R&D monies this year. Industry, of course, has a vested interest in R&D, which has the potential for industrial applications and commercialization. This year it will contribute 52% ($81.1 billion) of total R&D spending compared with the federal government's 43% ($68.2 billion). But the effect of the federal government on R&D goes beyond funding, because government policies have an impact on industrial support for R&D. Environmental regulations, for example, influence the direction of R&D.

1 OVERVIEW
Who funds R&D and who does the work. Who receives U.S. chemical patents. Fields in which chemical papers are published. **Page 42**

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4 UNIVERSITIES & COLLEGES
Who funds academic R&D and which schools spend the most, particularly for chemistry and chemical engineering. Degrees awarded in chemistry and chemical engineering. Postdoctoral appointments in science and engineering fields. **Page 58**

5 INTERNATIONAL
How R&D efforts in the U.S. compare with those of Japan, the former West Germany, France, Italy, and the U.K. Which countries publish most of the chemical literature. **Page 72**

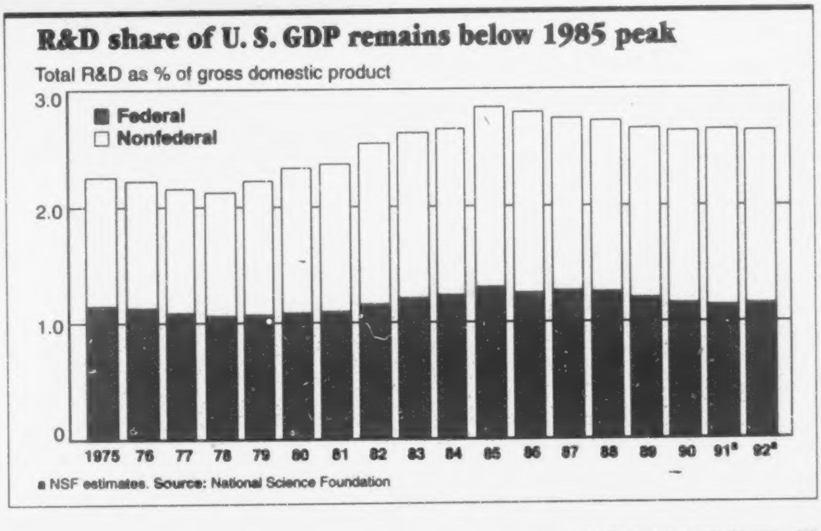
Industry, not surprisingly, is also the leading performer of R&D, accounting for 70% of this work in 1992, down a bit from the 74% of all R&D it performed in the mid-1980s. Universities and colleges, which will perform 12% of R&D in 1992, and the federal government's own laboratories, which will do 11% this year, account for most of the rest. University-based R&D, which has been growing at an annual rate of 10% for the past 10 years, is the fastest growing R&D sector.

In absolute expenditures, the U.S. R&D enterprise dwarfs that of other countries. In 1990, the latest year for which data are available for Japan and the former West Germany (the U.S.'s chief competitors in high-technology areas), the U.S spent more than twice

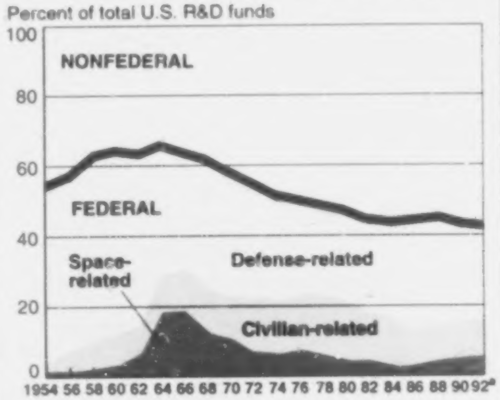
Engelhard photo

as much as Japan on R&D and four-and-a-half times as much as West Germany. But U.S. spending stalled in the late 1980s, remaining at $130 billion in 1990 (constant 1987 dollars), unchanged from the year before and less than 1% higher than in 1988. Japan's inflation-adjusted spending, on the other hand, grew 9% to $59.2 billion and West Germany's grew 2% to $28.8 billion in 1990. Moreover, Japan's spending grew at an annual rate of 7%, after inflation, versus the U.S.'s 4%, for the decade ending in 1990. The U.S. hasn't done any better since 1990, either. According to preliminary data from NSF, U.S. R&D funds fell 1% in real terms in 1991, and are expected to rise only 0.6% above their 1990 level this year.

The U.S. doesn't compare well with Japan or the former West Germany in R&D spending as a percentage of gross domestic product, either. Share of GDP—the value of all goods and services produced in a country—is a useful measure of the R&D efforts of different countries because it takes into account differences in the economic base for each country. The fraction of GDP spent on R&D in the U.S. declined in the second half of the eighties, dropping from 2.8% in 1985 to 2.7% in 1990. Both Japan and West Germany passed the U.S. by this measure in 1987, so that by 1990, Japan was spending 3.1% and West Germany 2.8% of their GDP on R&D. Moreover, virtually all of Japan's and 95% of West Germany's R&D allotments are designated for nondefense-related R&D. The U.S., however, takes away from civilian research by reserving a much larger chunk (27% in 1990) of R&D money for defense-related R&D. That dropped U.S. support for nondefense-related R&D to 1.9% of GDP in 1990.



Federal share of U.S. R&D funds has been declining since mid-60s



Note: Total R&D funds for 1992 = $157 billion. a NSF estimate.
Source: National Science Foundation

Another way to compare R&D efforts in the U.S. with those in other countries is to look at the number of patents issued. Last year, the U.S. garnered 51% of U.S. chemical patents—14,022 out of a total of 27,433—reversing a seven-year decline. That still leaves 49% of U.S. chemical patents originating abroad. Japan's share, at 21%, and Germany's, at 10%, were unchanged from the year before. Together, these two countries account for nearly a third of U.S. chemical patents.

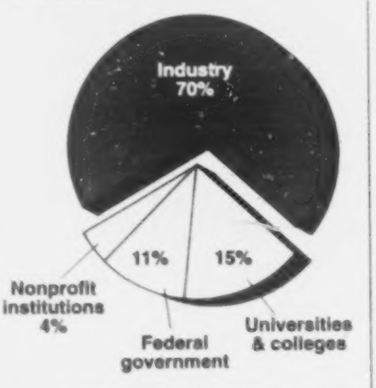
Growth of industrial R&D in the U.S. trailed inflation in 1991, with funding up just 2% over 1990. Makers of industrial chemicals showed even smaller increases, with their R&D spending up only an estimated 1% over 1990 and far behind their 5% average annual growth rate for the decade ending in 1991. Nevertheless, chemical and allied products companies as a whole, thanks largely to the R&D efforts of the pharmaceutical industry, increased R&D spending to an estimated $13.4 billion in 1991. That's up 7% from 1990, but still lags their 9% average annual growth for the past 10 years. Drug companies, which carry out 46% of the R&D performed by the chemical and allied products industry, boosted R&D spending 9%, also short of their 12% average annual growth rate for the decade.

R&D by U.S. companies abroad in 1990 enjoyed a bonanza year: Spending by chemical and allied products companies increased 33%, more than double their average annual growth rate for the decade. Drug companies, with a 46% hike in their spending, tripled their average annual growth rate for the decade.

In fiscal 1992, which will end Sept. 30, spending by the U.S. government for R&D will rise an estimated 11%, the largest increase in seven years, to $70.4 billion. Among other hikes called for in Congressional appropriations are 14% increases to the R&D budgets for NSF, the Department of Defense, and the Environmental Protection Agency and a 15% increase for the National Aeronautics & Space Administration. Chemistry should gain: EPA could support research on clean fuels or nuclear energy, for example, and DOD could fund research in weapons-related areas such as composites and high-temperature alloys.

In fact, NSF estimates the federal government will spend $872 million for research in chemistry in fiscal 1992. This represents an increase of 5% over 1991, a bit better than the 4% average annual growth rate from 1985 to 1992. Five agencies provide nearly 80% of these funds—the Department of Energy, 21%; NSF, 18%; DOD, 15%; Health & Human Services, 15%; and the Department of Agriculture, 9%. Research performed at universities claims $351 million of the federal allotment for chemical research, and just two agencies provide 70% of this funding—NSF (44%) and HHS (26%).

Industry spends 70% of all R&D funds



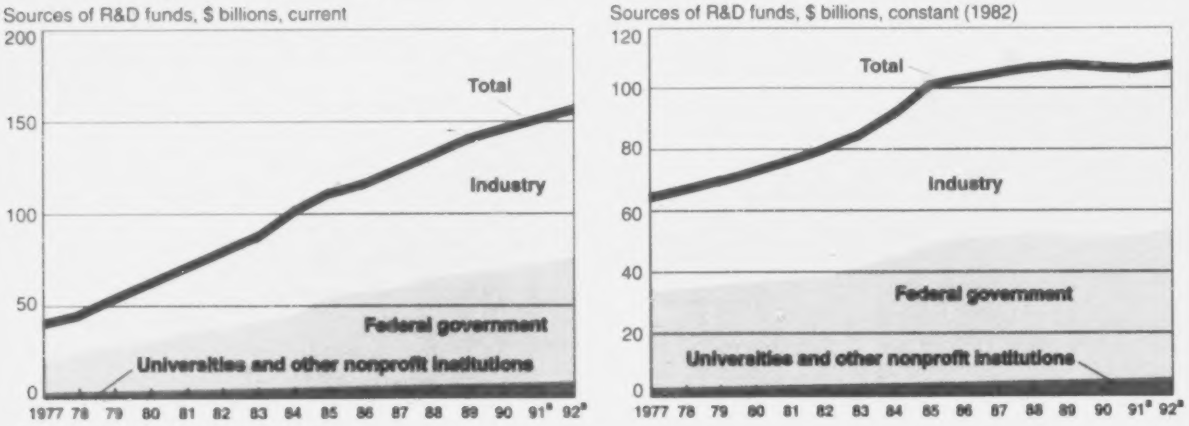
Total 1992 R&D spending = $157 billion[a]

a NSF estimate. **Source:** National Science Foundation

Universities' spending for both research and development in chemistry, even after adjusting for inflation, grew 68% in the period 1980 to 1990. Of the $649 million spent in 1990, 68% came from the federal government. Chemical R&D accounts for only 5% of academic R&D spending in all sciences. But many chemistry-related areas such as biochemistry and molecular biology fall under the umbrella of life sciences, which accounted for 64% of academic spending in the sciences in 1990. Thus, a significant amount of chemical research is probably included here, judging by the distribution of abstracts of papers in *Chemical Abstracts*. For example, the various subdisciplines of biochemistry have accounted for about 40% of all papers abstracted by Chemical Abstracts Service throughout the decade ending in 1991.

Foreign graduate students, whose numbers have been growing at an annual rate of 6% since 1985, represented a fifth of all graduate students in the U.S. in 1990, NSF indicates. But they make up a much larger proportion of graduate students in chemistry (32%) and chemical engineering (42%). The number of bachelor's degrees in chemistry, which has been declining for more than 10 years, was down 29% in 1990 compared with 1980. In chemical engineering, bachelor's degrees surged from 1976 to 1985, then dropped off sharply so that by 1990 it was down 46% compared with 1980. Ph.D. degrees in both fields have generally risen through the decade—up 41% in chemistry and 98% in chemical engineering since 1980. Very likely the increase in foreign graduate students contributes substantially to the increase in Ph.D.s, although some B.S. chemistry graduates, faced with a tight job market, may opt for graduate school. In any case, fewer and fewer U.S. citizens are obtaining B.S. degrees in chemistry or chemical engineering. And, if foreign students are required by U.S. immigration laws to return to their home country after graduating, chemistry and chemical engineering graduates may be in short supply. ☐

Funding Barely Keeps Pace With Inflation



In current dollars, total R&D spending rose 26% in past five years . . .

Sources of R&D funds, $ billions, current

. . . but in real terms that represents a mere 4% increase

Sources of R&D funds, $ billions, constant (1982)

a Preliminary. **Source:** National Science Foundation

SOURCES OF R&D FUNDS: Industry and federal government contribute 95%

												% annual change	
$ Billions, current	1992ª	1991ª	1990	1989	1988	1987	1986	1985	1984	1983	1982	1991–92	1982–92
Industry	$ 81.1	$ 78.3	$ 75.5	$ 72.1	$ 67.0	$ 62.6	$ 61.1	$ 58.0	$ 52.2	$45.3	$40.7	4%	7%
Federal government	68.2	65.2	63.9	62.6	61.5	57.9	54.3	52.1	45.6	40.8	36.6	5	6
Universities and colleges	5.3	4.8	4.4	3.9	3.5	3.2	2.8	2.4	2.1	1.9	1.7	10	12
Other nonprofit institutions	2.9	2.6	2.3	2.1	1.8	1.6	1.4	1.3	1.2	1.1	1.0	12	11
TOTAL	**$157.4**	**$150.8**	**$146.2**	**$140.8**	**$133.7**	**$125.4**	**$119.5**	**$113.8**	**$101.1**	**$89.1**	**$80.0**	**4%**	**7%**
ANNUAL CHANGE	**4%**	**3%**	**4%**	**5%**	**7%**	**5%**	**5%**	**13%**	**13%**	**11%**	**11%**		
$ Billions, constant 1982													
Industry	$ 56.2	$ 56.0	$ 56.1	$ 55.7	$ 54.0	$ 52.5	$ 52.9	$ 51.5	$ 48.1	$43.5	$40.7	2%	4%
Federal government	47.3	46.7	47.4	48.3	49.6	48.5	47.0	46.3	42.0	39.2	36.6	3	3
Universities and colleges	3.6	3.4	3.3	3.0	2.8	2.7	2.4	2.1	1.9	1.8	1.7	9	8
Other nonprofit institutions	2.0	1.9	1.7	1.6	1.5	1.3	1.2	1.2	1.1	1.1	1.0	5	7
TOTAL	**$109.2**	**$108.0**	**$108.5**	**$108.8**	**$107.8**	**$105.1**	**$103.4**	**$101.1**	**$ 93.1**	**$85.6**	**$80.0**	**1%**	**3%**
ANNUAL CHANGE	**1%**	**–1%**	**0%**	**1%**	**3%**	**2%**	**2%**	**9%**	**9%**	**7%**	**5%**		

Note: Constant-dollar values are calculated by C&EN from NSF data. Totals may not add up because of rounding. **a** Preliminary figures, NSF estimates. **Source:** National Science Foundation

PERFORMERS OF R&D: Universities' share, though only 12% of total, is rising fastest

$ Billions, current	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	1984	1983	1982	% annual change 1991–92	% annual change 1982–92
Industry	$110.3	$106.8	$104.3	$101.9	$ 97.9	$ 92.2	$ 87.8	$ 84.2	$ 74.8	$65.3	$58.7	3%	7%
Federal government	17.6	16.5	16.0	15.1	14.3	13.4	13.5	12.9	11.6	10.6	9.1	7	7
Universities and colleges	19.0	17.5	16.3	15.0	13.5	12.2	10.9	9.7	8.6	7.9	7.3	9	10
University-associated FFRDCs[b]	5.1	5.0	4.8	4.7	4.5	4.2	3.9	3.5	3.2	2.7	2.5	2	7
Other nonprofit institutions	5.5	5.2	4.7	4.1	3.6	3.4	3.4	3.4	3.0	2.7	2.4	6	9
TOTAL	**$157.4**	**$150.8**	**$146.1**	**$140.8**	**$133.7**	**$125.4**	**$119.5**	**$113.8**	**$101.1**	**$89.1**	**$80.0**	**4%**	**7%**
$ Billions, constant 1982													
Industry	$ 77.8	$ 76.5	$ 77.4	$ 78.7	$ 79.0	$ 77.3	$ 76.0	$ 74.8	$ 68.9	$62.7	$58.7	2%	3%
Federal government	12.4	11.8	11.9	11.7	11.5	11.2	11.6	11.5	10.7	10.2	9.1	5	3
Universities and colleges	13.4	12.5	12.1	11.6	10.9	10.2	9.4	8.6	7.9	7.6	7.3	7	6
University-associated FFRDCs[b]	3.6	3.6	3.6	3.6	3.6	3.5	3.4	3.1	2.9	2.6	2.5	0	4
Other nonprofit institutions	3.8	3.7	3.5	3.2	2.9	2.8	2.9	3.0	2.8	2.6	2.4	3	4
TOTAL	**$111.0**	**$108.0**	**$108.5**	**$108.8**	**$107.8**	**$105.1**	**$103.4**	**$101.1**	**$ 93.1**	**$85.6**	**$80.0**	**3%**	**3%**

Note: Constant dollar values are calculated by C&EN based on NSF data. Totals may not add up because of rounding. **a** Preliminary figures. NSF estimates. **b** Federally funded R&D centers.
Source: National Science Foundation

U.S. CHEMICAL PATENTS: Total gained 6% last year, those of U.S. origin jumped 8%

Number of patents issued	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	Total 1982–91
U.S. origin	**14,022**	**13,028**	**13,795**	**11,245**	**11,395**	**10,505**	**11,533**	**11,504**	**10,553**	**10,614**	**118,194**
to U.S. corporations	12,217	11,240	12,037	9,848	9,900	9,199	10,175	10,119	9,142	9,173	103,050
to U.S. government	335	312	297	259	323	288	321	375	329	311	2,238
to individuals in the U.S.	1,271	1,300	1,299	1,014	1,047	924	986	934	986	1,029	10,790
to foreign-owned corporations in the U.S.	199	176	162	124	125	94	51	76	96	101	1,204
Foreign origin	**13,411**	**12,794**	**13,156**	**10,555**	**10,258**	**9,116**	**9,693**	**8,997**	**8,067**	**8,017**	**104,064**
to U.S.-owned corporations abroad	1,105	1,095	1,134	855	847	757	883	835	701	731	8,943
to foreign corporations	11,387	10,818	11,118	8,946	8,657	7,681	8,083	7,441	6,712	6,517	87,360
to foreign governments	197	153	176	170	200	148	161	166	133	164	1,668
to foreign individuals	722	728	728	584	554	530	566	555	521	605	6,093
TOTAL	**27,433**	**25,822**	**26,951**	**21,800**	**21,653**	**19,621**	**21,226**	**20,501**	**18,620**	**18,631**	**222,258**
% FOREIGN	**48.9%**	**49.5%**	**48.8%**	**48.4%**	**47.4%**	**46.5%**	**45.7%**	**43.8%**	**43.3%**	**43.0%**	**46.8%**

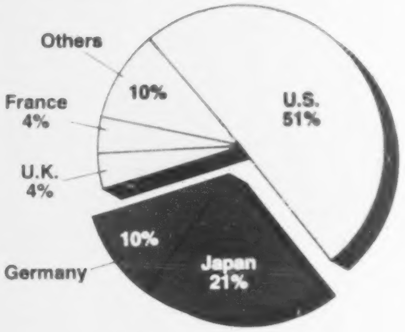
Note: Includes patents issued in those technology subclasses that the U.S. Patent & Trademark Office classifies as chemical. **Source:** U.S. Patent & Trademark Office

RECIPIENTS OF U.S. CHEMICAL PATENTS: U.S.'s share edged up, reversing seven-year decline

% of patents issued	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	Total 1982–91
U.S. origin	**51%**	**50%**	**51%**	**52%**	**53%**	**54%**	**54%**	**56%**	**57%**	**57%**	**53%**
Foreign origin	**49**	**50**	**49**	**48**	**47**	**46**	**46**	**44**	**43**	**43**	**47**
Japan	21	21	20	20	19	19	18	16	15	14	18
Germany[a]	10	10	10	11	10	11	10	10	11	11	10
U.K.	4	4	4	4	4	4	4	4	4	4	4
France	4	4	3	4	4	3	3	3	3	4	4
Switzerland	2	2	2	2	2	2	2	2	2	2	2
Canada	2	2	2	2	1	1	2	1	1	1	2
Italy	2	2	2	1	1	1	1	1	1	1	1
Netherlands	1	1	1	1	1	1	1	1	1	1	1
Sweden	1	1	1	1	1	1	1	1	1	1	1
Belgium	1	1	1	1	1	1	1	1	1	1	1

Note: Includes patents issued in those technology subclasses that the U.S. Patent & Trademark Office classifies as chemical. **a** Patents prior to October 1990 were issued to West Germany. **Source:** U.S. Patent & Trademark Office

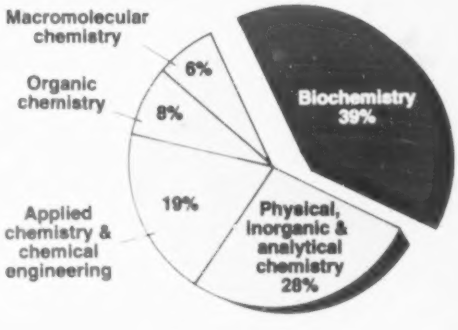
Nearly a third of U.S. chemical patents originate in Germany and Japan



1991 total U.S. chemical patents issued = 27,433

Source: U.S. Patent & Trademark Office

Biochemistry contributes nearly 40% of chemistry papers



1991 total[a] = 453,640

[a] Number of abstracts of papers published in *Chemical Abstracts*.
Source: Chemical Abstracts Service

PATENT ACTIVITY OF U.S. COMPANIES: Du Pont, Ciba-Geigy, and Dow claim lion's share

Number of patents issued	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	Total 1982–91
CHEMICAL COMPANIES											
Du Pont[a]	651	533	495	437	449	371	396	416	387	331	**4,466**
Ciba-Geigy	414	409	346	279	286	244	307	290	244	281	**3,100**
Dow Chemical	332	400	431	421	469	371	336	328	246	277	**3,611**
Dow Corning	135	122	105	82	58	68	55	52	37	35	**749**
Union Carbide	131[b]	127[b]	132	141	159	208	242	231	182	202	**1,755**
Monsanto	129	84	87	76	91	111	100	138	136	131	**1,083**
W. R. Grace	121	105	111	61	44	43	45	57	52	49	**688**
Air Products	119	98	119	70	85	61	80	60	49	54	**795**
Ethyl	118	108	87	51	48	77	105	76	44	31	**745**
American Cyanamid	106	136	114	101	107	92	115	111	128	129	**1,139**
Olin	105	74	80	60	58	81	117	112	86	80	**853**
PPG Industries	93	100	112	118	118	124	128	137	137	177	**1,244**
Hercules	63	35	47	32	50	43	41	39	37	30	**417**
Rohm & Haas	49	32	32	18	22	33	31	37	55	49	**358**
GAF Chemicals	40	42	50	23	15	12	23	19	21	32	**277**
International Flavors & Fragrances	38	40	31	24	38	76	104	95	87	87	**620**
TOTAL[c]	**2644**	**2445**	**2379**	**1994**	**2097**	**2015**	**2225**	**2198**	**1928**	**1975**	**21,900**
ANNUAL CHANGE	**8%**	**3%**	**19%**	**–5%**	**4%**	**–9%**	**1%**	**14%**	**–2%**	**–19%**	
DRUG COMPANIES											
Merck	152	134	173	125	123	103	105	135	115	135	**1,300**
Warner-Lambert	120	108	117	113	118	101	73	49	34	25	**858**
Pfizer	91	82	79	63	67	72	72	89	61	72	**748**
Abbott Laboratories	79	64	39	39	30	29	36	32	32	50	**430**
Hoffmann-LaRoche	78	78	93	59	86	84	74	78	90	118	**838**
Eli Lilly	66	73	75	68	85	82	107	80	74	104	**814**
American Home Products	46	66	78	69	46	38	49	32	24	43	**491**
Upjohn	23	26	30	15	26	66	66	109	73	123	**557**
SmithKline Beckman	13	29	62	56	54	28	43	68	59	66	**478**
TOTAL[c]	**668**	**660**	**746**	**607**	**635**	**603**	**625**	**672**	**562**	**736**	**6,514**
ANNUAL CHANGE	**1%**	**–12%**	**23%**	**–4%**	**5%**	**–3%**	**–7%**	**20%**	**–24%**	**–29%**	

Note: Includes U.S. chemical and drug companies and U.S. subsidiaries of foreign companies that have received more than 1000 U.S. patents since 1962. **a** Includes patents issued to Conoco, acquired in 1981, for all years. **b** Includes patents issued to Union Carbide Chemicals & Plastics, Union Carbide Chemicals & Plastics Technology, and Union Carbide Industrial Gases Technology. **c** These totals include patents issued to companies in this table only. **Source:** U.S. Patent & Trademark Office

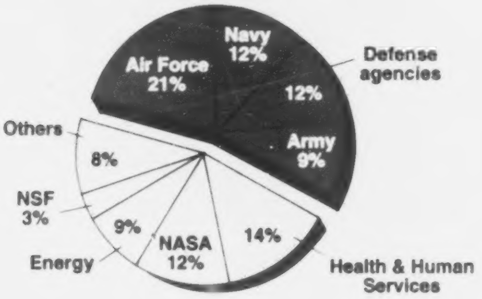
ABSTRACTS OF PAPERS IN *CHEMICAL ABSTRACTS*: Fields' shares changed little in decade

	1991	1990	1989	1988	1987	1986	1985	1984	1981	% change 1981–91
BIOCHEMISTRY	39.5%	36.9%	39.2%	39.7%	40.5%	40.4%	40.5%	40.5%	39.0%	0.5%
% of all biochemistry abstracts										
Mammalian hormones[a]	12.2	11.5	12.0	12.0	12.2	12.5	12.3	12.4	6.8	5.4
Mammalian biochemistry[a]	12.0	10.5	10.7	10.8	11.1	10.8	11.1	11.3	15.6	−3.6
Pharmacology	11.4	11.7	12.6	12.7	12.6	12.2	12.3	11.6	12.4	−1.0
Biochemical genetics[b]	9.0	10.1	7.9	7.6	6.7	6.1	5.2	4.2	—	—
Toxicology	6.9	6.7	7.8	7.9	8.3	7.8	7.9	8.0	8.7	−1.8
Immunochemistry	6.2	6.8	6.3	5.8	5.8	6.1	5.3	4.8	3.4	2.8
Enzymes	5.9	6.1	6.1	6.1	5.4	5.6	5.6	5.8	5.9	0
Biochemical methods	5.2	4.7	5.1	5.1	4.8	5.0	4.9	4.9	5.7	−0.5
Plant biochemistry[a]	5.1	5.1	4.6	5.0	5.3	5.2	5.5	6.2	5.8	−0.7
Microbial biochemistry[a]	4.7	5.4	5.1	4.8	5.1	5.7	5.7	5.2	5.6	−0.9
General biochemistry	4.7	5.2	5.1	5.3	4.6	4.7	4.9	5.3	7.5	−2.8
Others	16.7	16.2	16.7	16.9	18.1	18.3	19.3	20.3	22.6	−5.9
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	—
PHYSICAL, INORGANIC, AND ANALYTICAL CHEMISTRY	28.4%	30.3%	29.0%	28.8%	29.0%	29.8%	29.8%	28.8%	28.0%	0.4%
% of all physical, inorganic, and analytical chemistry abstracts										
Spectra	18.1	16.9	18.1	20.0	20.4	20.0	18.4	18.0	18.0	0.1
Nuclear chemistry	16.3	17.1	19.4	17.8	19.5	19.9	21.8	22.2	21.6	−5.3
Electric phenomena	14.8	13.2	13.9	12.5	10.9	10.8	10.8	10.8	11.0	3.8
General physical chemistry	7.3	7.7	6.9	7.2	7.9	7.0	6.9	6.9	7.2	0.1
Analytical chemistry	6.4	7.9	5.1	5.7	5.9	6.8	6.1	6.3	5.8	0.6
Crystallography and liquid crystals	7.4	7.3	7.8	7.0	7.1	7.0	7.5	7.8	8.9	−1.5
Surface chemistry and colloids	6.3	6.0	5.7	5.8	5.0	4.7	4.9	4.5	4.5	1.8
Others	23.4	23.9	23.1	24.0	23.3	23.8	23.6	23.5	23.0	−0.4
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	—
APPLIED CHEMISTRY AND CHEMICAL ENGINEERING	18.9%	18.2%	18.1%	18.6%	18.0%	18.2%	18.4%	17.6%	19.1%	−0.2%
% of all applied chemistry and chemical engineering abstracts										
Metals and alloys	21.2	24.5	22.1	21.7	20.6	20.8	20.0	18.9	17.9[a]	3.3
Water, wastes, and pollution	22.2	18.8	17.8	20.4	20.4	21.9	20.2	21.0	24.0	−1.8
Ceramics	9.1	9.4	9.1	6.7	6.3	5.8	5.6	5.1	4.8	4.3
Fossil fuels, derivatives, and related products	8.8	8.0	8.7	8.8	9.6	9.0	10.1	10.1	9.4	−0.6
Unit operations and processes	8.3	9.2	10.3	8.0	9.0	7.1	7.5	7.0	6.4	1.9
Pharmaceuticals and pharmaceutical analysis	7.6	8.2	7.8	7.6	7.8	8.2	8.0	7.0	7.5	0.1
Mineralogical and geological chemistry	10.1	7.8	9.3	11.8	11.2	12.0	12.5	14.6	14.1	−4.0
Others	12.7	14.1	14.9	15.0	15.1	15.2	16.1	16.3	15.9	−3.2
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	—
ORGANIC CHEMISTRY	7.6%	8.7%	7.8%	7.3%	6.9%	5.9%	6.4%	7.6%	8.7%	−1.1%
% of all organic chemistry abstracts										
Physical organic chemistry	21.3	21.2	25.9	23.0	23.9	27.3	30.6	32.0	37.0	−15.7
Heterocyclic compounds[a]	19.0	17.4	16.1	18.8	19.9	15.0	16.1	15.6	18.2	0.8
Organometallic and organometalloidal compounds	16.6	20.4	18.4	15.7	16.1	18.3	16.2	17.1	8.3	8.3
Carbohydrates	8.5	7.4	6.5	8.1	5.6	7.8	5.7	5.7	5.4	3.1
Amino acids, peptides, and proteins[a]	7.3	6.0	4.5	5.8	4.3	3.9	4.6	4.8	4.2	3.1
Aromatic compounds[a]	6.8	7.1	6.9	7.2	7.7	7.3	6.3	6.3	8.7	−1.9
Biomolecules and their synthetic analogs[b]	5.8	5.9	5.8	6.1	5.8	5.0	4.9	4.4	—	—
Others	14.7	14.6	15.9	15.3	16.7	15.4	15.6	14.1	18.2	−3.5
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	—
MACROMOLECULAR CHEMISTRY	5.6%	5.9%	5.9%	5.6%	5.6%	5.7%	4.9%	5.5%	5.2%	0.4%
% of all macromolecular chemistry abstracts										
Synthetic high polymers	39.5	38.6	34.4	34.8	35.2	34.1	34.1	34.0	30.3	9.2
Plastics manufacture and uses	25.8	23.3	25.1	23.7	23.6	23.8	25.3	24.2	26.4	−0.6
Textiles	7.1	6.7	7.2	7.3	8.1	8.8	8.2	7.3	9.9	−2.8
Cellulose, lignin, paper, and other wood products	6.3	7.6	9.2	9.6	8.8	9.8	9.1	9.6	10.1	−3.8
Industrial organic chemicals, leather, fats, and waxes[b]	5.6	8.4	8.1	6.8	5.6	4.6	4.4	4.8	—	—
Synthetic elastomers and natural rubber	5.6	4.8	5.6	6.7	7.2	6.7	6.8	7.3	7.9	−2.3
Coatings, inks, and related products	5.5	5.2	5.6	5.7	5.8	7.2	7.2	7.8	7.5	−2.0
Others	4.6	5.4	4.8	5.4	5.7	5.0	4.9	5.0	7.9	−3.3
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	—

How to read this table: Using biochemistry as an example, in 1991 39.5% of all the papers abstracted by Chemical Abstracts Service are in the various subdisciplines of biochemistry; 12.2% of all abstracts in biochemistry, in turn, are in the subdiscipline of mammalian hormones, and so on. **a** Definition of section changed in 1982. **b** New section in 1982. **Source:** Chemical Abstracts Service

Defense, Civilian Funding Move Toward Parity

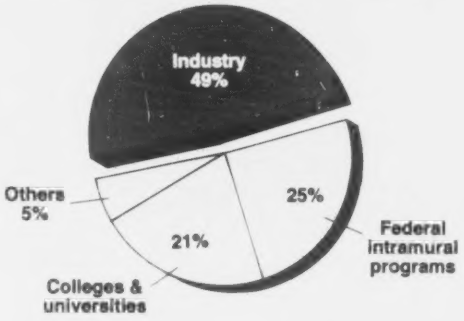
Defense Department funds just over half of federal R&D efforts . . .



Estimated fiscal 1992 total federal R&D obligations = $70.4 billion

Source: National Science Foundation

. . . and just under half of federally funded R&D is performed by industry



Estimated fiscal 1992 total federal R&D obligations = $70.4 billion

FEDERAL OBLIGATIONS FOR R&D: Defense programs bounce back

$ Millions	1992ᵃ	1991ᵃ	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
Defense	**$38,770**	**$33,966**	**$37,268**	**$37,577**	**$35,415**	**$35,232**	**$32,938**	**$29,792**	**14%**	**5%**
Air Force	15,116	11,900	14,831	15,237	15,034	15,348	13,594	13,261	27	3
Defense agencies	8,481	7,446	6,945	6,859	5,833	5,220	4,767	2,782	14	25
Navy	8,427	8,850	9,586	9,666	9,514	9,508	9,650	9,127	–5	–1
Army	6,458	5,557	5,684	5,659	4,806	5,020	4,809	4,571	16	7
Health & Human Services	**9,781**	**9,246**	**8,406**	**7,903**	**7,158**	**6,606**	**5,658**	**5,451**	**6**	**12**
National Institutes of Health	8,253	7,705	7,137	6,778	6,291	5,851	5,005	4,828	7	11
Alcohol, Drug Abuse & Mental Health Administration	1,022	957	843	696	555	476	396	378	7	22
NASA	**8,543**	**7,435**	**6,533**	**5,394**	**4,330**	**3,787**	**3,420**	**3,327**	**15**	**21**
Energy	**6,499**	**6,159**	**5,631**	**5,193**	**5,036**	**4,757**	**4,688**	**4,966**	**6**	**6**
NSF	**2,102**	**1,847**	**1,690**	**1,670**	**1,533**	**1,471**	**1,353**	**1,346**	**14**	**9**
Agriculture	**1,256**	**1,219**	**1,108**	**1,038**	**1,017**	**948**	**929**	**943**	**3**	**6**
Agricultural Research Service	624	589	546	524	506	479	463	470	6	6
Cooperative State Research Service	373	377	324	307	298	271	269	284	–1	6
Forest Service	163	168	159	131	136	127	113	113	–3	8
EPA	**483**	**425**	**420**	**380**	**347**	**348**	**317**	**320**	**14**	**9**
Interior	**562**	**589**	**509**	**469**	**417**	**404**	**385**	**392**	**–5**	**7**
Geological Survey	339	354	308	280	236	227	219	215	–4	10
Commerce	**539**	**526**	**438**	**398**	**389**	**402**	**399**	**399**	**2**	**6**
National Oceanic & Atmospheric Administration	377	336	300	269	263	286	275	270	12	7
National Institute of Standards & Technology	186	176	122	116	108	99	101	101	6	13
Others	**1,892**	**1,806**	**1,664**	**1,384**	**1,293**	**1,298**	**1,325**	**1,424**	**5**	**7**
TOTAL	**$70,427**	**$63,218**	**$63,667**	**$61,406**	**$56,935**	**$55,253**	**$51,412**	**$48,360**	**11%**	**8%**
ANNUAL CHANGE	**11%**	**–1%**	**4%**	**8%**	**3%**	**7%**	**6%**	**14%**		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

PERFORMERS OF FEDERALLY FUNDED R&D: Industry's share is growing

Federal obligations, $ millions	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
Industry	$34,307	$29,237	$31,616	$30,508	$28,630	$28,628	$25,898	$23,496	17%	6%
FFRDCs[b] administered by industry	2,377	2,267	2,238	1,960	1,911	1,860	1,697	1,791	5	4
Federal intramural programs	17,645	16,469	16,003	15,121	14,115	13,413	13,535	12,945	7	7
Universities and colleges	14,601	13,763	12,608	12,169	11,302	10,547	9,327	9,156	6	7
FFRDCs[b] administered by universities	4,126	3,695	3,466	3,497	3,474	3,210	2,768	2,816	12	6
Nonprofit institutions	3,333	3,226	2,882	2,521	2,188	2,222	2,228	2,388	3	5
FFRDCs[b] administered by nonprofit institutions	714	676	632	522	506	511	551	689	6	1
Foreign	292	282	345	919	392	295	296	245	4	3
State and local governments	250	241	214	167	142	148	128	129	4	10
TOTAL	$70,427	$63,218	$63,667	$61,406	$56,769	$55,253	$51,412	$48,359	11%	6%
ANNUAL CHANGE	11%	–1%	4%	8%	3%	7%	6%	15%		

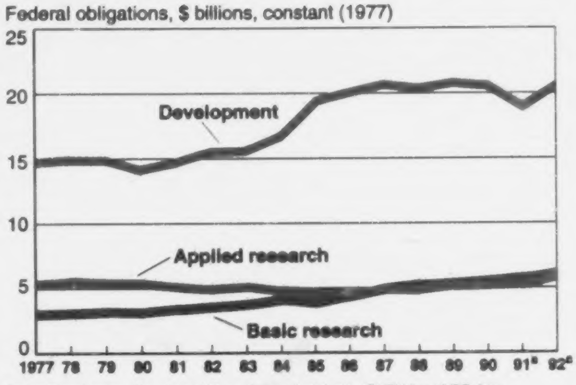
Note: Fiscal years **a** Estimated **b** Federally funded R&D centers **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR SCIENTIFIC DISCIPLINES: Physical sciences post 10% gain

$ Millions for research only	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
Life sciences	$10,230	$ 9,670	$ 8,838	$ 8,495	$ 7,724	$ 7,341	$ 6,464	$ 6,363	6%	7%
Engineering	5,359	4,924	4,335	4,442	3,956	3,906	3,739	3,616	9	6
Metallurgy and materials	592	685	555	521	457	362	445	439	–14	4
Chemical	218	273	242	142	258	216	246	254	–20	–2
Physical sciences	4,523	4,123	3,809	3,705	3,317	3,253	3,069	3,046	10	6
Physics	2,610	2,423	2,255	2,191	1,975	1,854	1,806	1,816	8	5
Chemistry	872	834	762	783	703	680	662	650	5	4
Environmental sciences	2,627	2,450	2,174	1,773	1,607	1,512	1,482	1,404	7	9
Mathematical and computer sciences	1,007	946	841	735	643	641	615	575	6	8
Other sciences	1,937	1,958	1,742	1,615	1,402	1,287	1,133	1,129	–1	8
TOTAL	$25,683	$24,071	$21,739	$20,765	$18,649	$17,940	$16,502	$16,133	7%	7%
ANNUAL CHANGE	7%	11%	5%	11%	4%	9%	2%	8%		

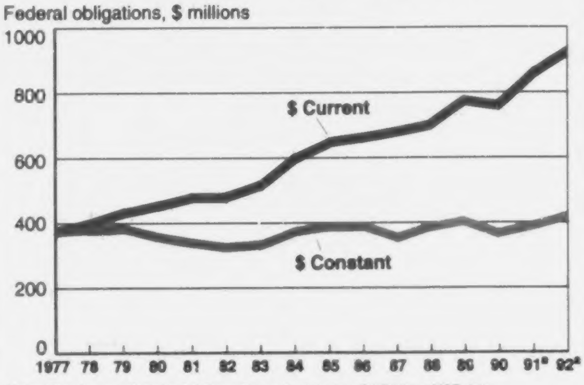
Note: Fiscal years **a** Estimated **Source:** National Science Foundation

Real support for basic research climbed 85% over past 15 years



Note: Fiscal years. Constant-dollar values calculated by C&EN from NSF data. **a** Estimated. **Source:** National Science Foundation

In constant dollars, support for chemical research rose 9% since 1977



Note: Fiscal years. Constant-dollar values calculated by C&EN from NSF data. **a** Estimated. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR BASIC RESEARCH: NIH provides almost 40% of the money

$ Millions	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
Health & Human Services	$ 5,419	$ 5,042	$ 4,649	$ 4,388	$4081	$3828	$3339	$3233	7%	8%
National Institutes of Health	4,961	4,609	4,262	4,053	3795	3576	3119	3018	8	7
Alcohol, Drug Abuse & Mental Health Administration	456	431	386	308	266	232	203	197	6	13
NSF	1,956	1,732	1,586	1,563	1433	1371	1275	1262	13	6
NASA	1,944	1,729	1,637	1,417	1113	1014	917	751	12	15
Energy	1,731	1,726	1,505	1,411	1185	1069	960	943	0	9
Defense	1,028	1,140	948	948	877	908	924	861	–10	3
Navy	425	397	365	354	342	354	337	343	7	3
Air Force	212	185	197	203	196	222	217	198	15	1
Defense agencies	199	380	200	204	173	115	122	79	–48	14
Army	193	178	185	187	166	217	249	241	8	–3
Agriculture	598	563	519	485	481	446	433	445	6	4
Agricultural Research Service	336	318	294	283	271	253	248	250	6	4
Cooperative State Research Service	189	170	154	143	146	133	132	142	11	4
Forest Service	62	64	60	50	52	49	42	44	–3	5
Interior	210	233	205	189	127	135	133	138	–10	6
Geological Survey	168	182	159	140	90	85	83	81	–8	11
Bureau of Mines	34	44	41	44	32	46	45	50	–23	–6
EPA	114	97	74	51	27	31	39	39	18	17
Commerce	34	32	31	29	31	26	27	23	6	6
National Institute of Standards & Technology	33	30	29	28	26	25	26	22	10	6
Others	174	152	132	121	120	114	106	124	14	4
TOTAL	$13,208	$12,446	$11,286	$10,602	$9475	$8942	$8153	$7819	6%	5%
ANNUAL CHANGE	6%	10%	6%	12%	6%	10%	4%	11%		

Note: Fiscal years. a Estimated. **Source**: National Science Foundation

ENGINEERING RESEARCH: Funding for chemical engineering has yo-yoed since 1987, rising

Federal obligations, $ millions	1992[a] All engineering	1992[a] Chemical engineering	1992[a] Metallurgy & materials	1991[a] All engineering	1991[a] Chemical engineering	1991[a] Metallurgy & materials	1990 All engineering	1990 Chemical engineering	1990 Metallurgy & materials
Defense	$1963.1	$31.2	$386.6	$1972.2	$ 32.4	$487.8	$1762.2	$ 37.4	$370.5
Defense agencies	574.2	0.3	244.6	720.8	0	359.4	509.8	0	240.8
Air Force	494.7	3.7	45.7	419.0	3.3	38.6	466.7	1.8	42.6
Navy	478.4	11.2	68.3	443.8	10.3	62.5	408.8	11.5	59.7
Army	415.8	16.0	28.0	388.5	18.7	27.2	377.0	24.0	27.3
NASA	1960.7	16.4	81.5	1519.2	13.4	68.4	1324.6	14.3	59.8
Energy	488.6	69.2	73.1	528.3	138.7	78.1	435.6	105.9	78.5
NSF	220.6	44.4	9.7	186.8	38.5	8.4	171.6	35.9	7.8
Transportation	108.3	6.2	1.0	117.8	6.8	0.9	91.9	7.0	0.2
Interior	83.7	9.7	25.8	100.8	6.9	27.6	88.4	5.8	25.1
EPA	72.6	28.4	0.6	64.9	25.0	0.5	61.5	24.5	0.7
Commerce	76.0	4.2	13.6	70.8	4.0	13.6	56.8	3.9	11.8
Agriculture	36.8	7.9	0	41.2	7.8	0	38.9	7.3	0
TOTAL	$5010.4	$217.6	$591.9	$4602.0	$273.5	$685.3	$4031.5	$242.0	$554.4
ANNUAL CHANGE	9%	–20%	–14%	14%	13%	24%	–5%	70%	6%

Note: Fiscal years. a Estimated. **Source**: National Science Foundation

FEDERAL OBLIGATIONS FOR CHEMICAL RESEARCH: Growing by just 4% per year

$ Millions	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
Energy	$182.3	$214.4	$189.2	$213.4	$162.9	$145.5	$145.9	$143.0	–15%	4%
NSF	156.0	140.9	133.2	127.4	120.6	115.3	112.6	115.6	11	4
Defense	132.3	118.4	121.0	133.5	125.0	144.9	163.4	156.4	12	–3
Army	51.7	43.0	50.4	60.4	57.5	72.2	81.4	78.2	20	–5
Air Force	46.9	40.0	41.2	43.2	43.6	43.3	42.0	39.5	17	2
Navy	30.5	29.2	26.5	25.5	22.1	28.4	39.1	38.3	4	–4
Defense agencies	3.2	6.3	2.8	4.4	1.8	1.1	0.9	0.4	–49	35
Health & Human Services	131.7	122.4	112.2	107.8	123.8	115.5	104.2	99.1	8	4
National Institutes of Health	118.8	110.7	102.2	98.6	114.4	108.1	99.5	95.1	7	3
Alcohol, Drug Abuse & Mental Health Administration	12.9	11.7	9.9	9.2	9.4	7.4	4.7	4.0	10	18
Agriculture	78.3	75.4	67.8	61.0	60.8	65.0	58.6	58.0	4	4
Agricultural Research Service	50.7	47.9	43.1	41.3	40.9	46.4	40.0	36.1	6	5
Cooperative State Research Service	18.3	17.9	15.6	12.3	12.2	11.5	12.4	16.1	2	2
Forest Service	9.3	9.6	9.0	7.5	7.6	7.1	6.2	5.7	–3	2
EPA	63.0	44.7	37.1	32.5	30.6	34.6	20.1	17.5	41	7
NASA	57.9	41.3	35.9	47.4	27.5	13.4	11.8	16.3	40	20
Interior	28.5	28.3	22.9	22.0	21.9	20.9	20.3	19.4	1	6
Geological Survey	28.3	28.2	22.9	21.9	20.8	20.2	19.4	18.4	0	6
Commerce	26.9	27.2	25.0	24.4	23.6	22.9	19.1	17.7	–1	8
National Institute of Standards & Technology	20.9	19.5	18.4	17.7	16.9	16.5	16.4	15.4	7	4
National Oceanic & Atmospheric Administration	6.0	7.8	6.7	6.7	6.7	6.4	2.4	1.4	–23	23
Others	15.5	20.8	17.5	13.3	6.4	2.4	6.3	1.5	–25	39
TOTAL	$872.4	$833.8	$761.8	$782.8	$703.1	$680.4	$662.3	$644.5	5%	4%
ANNUAL CHANGE	5%	9%	–3%	11%	3%	3%	3%	6%		

Note: Fiscal years [a] Estimated **Source:** National Science Foundation

only 1%, whereas all engineering experienced a 35% increase

1989			1988			1987		
All engineering	Chemical engineering	Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials
$1836.2	$ 46.9	$343.4	$1636.1	$ 41.9	$294.4	$1629.7	$ 46.9	$203.6
565.1	0.2	221.6	416.8	0.1	174.8	325.6	0	79.8
480.5	11.6	42.9	455.1	1.8	43.2	460.3	1.8	34.5
389.9	11.6	56.1	379.8	19.6	52.5	401.5	21.3	57.2
400.6	23.4	22.7	384.4	20.3	23.8	442.4	23.8	32.1
1446.4	6.0	35.5	1138.2	2.0	18.8	1170.5	1.5	19.9
406.1	4.5	78.0	479.5	134.5	78.4	442.2	88.9	77.1
232.0	42.5	28.1	206.8	38.9	25.6	191.7	37.3	22.9
87.6	6.9	0.2	71.9	1.0	3.6	48.1	1.0	0.7
92.8	5.8	23.4	85.3	5.1	24.8	87.8	5.0	28.5
52.7	19.2	0.8	50.7	24.2	0.3	55.4	25.6	0.5
52.7	3.2	11.6	49.3	2.7	10.6	41.3	2.4	8.6
34.5	7.2	0	31.7	7.7	0	33.9	6.9	0
$4241.0	$142.2	$521.0	$3749.5	$258.0	$456.5	$3700.6	$215.5	$361.8
13%	–45%	14%	1%	20%	26%	5%	–12%	3%

FEDERAL OBLIGATIONS FOR APPLIED RESEARCH: NASA's budget up 29% in 1992

$ Millions	1992^a	1991^a	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
Health & Human Services	**$ 3,252**	**$ 3,159**	**$ 2,818**	**$ 2,700**	**$2416**	**$2194**	**$1851**	**$1796**	**3%**	**9%**
National Institutes of Health	2,385	2,248	2,074	2,008	1886	1740	1469	1410	6	8
Alcohol, Drug Abuse & Mental Health Administration	513	478	415	385	287	241	192	180	7	16
Defense	**2,883**	**2,665**	**2,582**	**2,708**	**2362**	**2440**	**2303**	**2307**	**8**	**3**
Defense agencies	1,060	1,049	965	1,038	792	751	735	738	1	5
Army	670	608	595	636	588	693	579	583	10	3
Air Force	639	527	579	605	577	563	542	538	21	3
Navy	515	482	443	429	406	433	447	448	7	2
NASA	**2,232**	**1,734**	**1,424**	**1,461**	**1219**	**1256**	**1152**	**1033**	**29**	**12**
Energy	**1,212**	**1,237**	**1,066**	**1,021**	**1051**	**1029**	**1081**	**1198**	**–2**	**0**
Agriculture	**614**	**614**	**550**	**517**	**505**	**473**	**464**	**466**	**0**	**4**
Agricultural Research Service	249	236	218	209	208	201	188	192	6	4
Cooperative State Research Service	185	206	171	165	153	138	137	143	–10	4
Forest Service	96	99	94	78	80	74	68	66	–3	6
Commerce	**418**	**413**	**346**	**322**	**312**	**313**	**313**	**301**	**1**	**5**
National Oceanic & Atmospheric Administration	291	292	252	235	225	234	238	224	0	4
National Institute of Standards & Technology	118	110	83	78	73	64	64	65	7	9
Interior	**310**	**316**	**270**	**253**	**266**	**247**	**235**	**231**	**–2**	**4**
Geological Survey	153	154	134	127	136	132	128	130	–1	2
EPA	**281**	**246**	**242**	**223**	**241**	**246**	**179**	**176**	**14**	**7**
NSF	**136**	**115**	**103**	**108**	**100**	**99**	**78**	**84**	**18**	**7**
Others	**1,137**	**1,123**	**1,052**	**848**	**703**	**697**	**691**	**723**	**1**	**7**
TOTAL	**$12,475**	**$11,622**	**$10,453**	**$10,161**	**$9175**	**$8994**	**$8347**	**$8315**	**7%**	**6%**
ANNUAL CHANGE	**7%**	**11%**	**3%**	**11%**	**2%**	**8%**	**0%**	**5%**		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR DEVELOPMENT: Biggest gains at Defense Department

$ Millions	1992^a	1991^a	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
Defense	**$34,858**	**$30,160**	**$33,739**	**$33,921**	**$32,010**	**$31,884**	**$29,711**	**$26,623**	**16%**	**5%**
Air Force	14,265	11,188	14,055	14,430	14,094	14,563	12,835	12,524	28	2
Navy	7,488	7,971	8,779	8,883	8,766	8,721	8,866	8,336	–6	–2
Defense agencies	7,222	6,018	5,780	5,617	4,868	4,354	3,911	1,965	20	30
Army	5,595	4,771	4,904	4,836	4,052	4,110	3,982	3,747	17	6
NASA	**4,367**	**3,971**	**3,473**	**2,515**	**1,999**	**1,518**	**1,351**	**1,544**	**10**	**16**
Energy	**3,556**	**3,196**	**3,060**	**2,761**	**2,801**	**2,659**	**2,648**	**2,825**	**11**	**3**
Health & Human Services	**1,109**	**1,046**	**939**	**814**	**661**	**584**	**468**	**423**	**6**	**15**
National Institutes of Health	907	848	801	717	610	536	418	400	7	12
Transportation	**299**	**269**	**247**	**182**	**213**	**256**	**317**	**358**	**11**	**–3**
Commerce	**87**	**81**	**61**	**47**	**47**	**64**	**60**	**75**	**7**	**2**
National Oceanic & Atmospheric Administration	46	43	48	34	35	52	37	45	7	0
National Institute of Standards & Technology	36	35	11	10	9	9	12	14	3	15
EPA	**87**	**83**	**104**	**107**	**80**	**71**	**100**	**106**	**5**	**–4**
Agriculture	**44**	**42**	**39**	**36**	**31**	**29**	**32**	**32**	**5**	**5**
Agricultural Research Service	38	36	33	31	26	24	27	28	6	5
Interior	**42**	**40**	**33**	**27**	**24**	**22**	**17**	**22**	**5**	**11**
Geological Survey	18	18	15	13	11	10	7	4	0	24
Others	**293**	**259**	**233**	**230**	**253**	**226**	**207**	**219**	**13**	**6**
TOTAL	**$44,742**	**$39,147**	**$41,928**	**$40,640**	**$38,119**	**$37,313**	**$34,911**	**$32,227**	**14%**	**7%**
ANNUAL CHANGE	**14%**	**–7%**	**3%**	**7%**	**2%**	**7%**	**8%**	**18%**		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

UNIVERSITY RESEARCH: Physical sciences get 13% of federal funds

Federal obligations, $ millions	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
Life sciences	$5288	$4990	$4532	$4396	$4029	$3824	$3252	$3192	6%	8%
Physical sciences	1152	1103	1002	930	857	823	752	750	4	6
Physics	624	621	546	486	425	404	405	402	0	7
Chemistry	351	330	317	298	295	281	266	267	6	4
Engineering	853	867	713	749	673	600	609	507	–2	8
Metallurgy and materials	182	215	166	194	175	108	133	107	–15	8
Chemical	48	45	59	42	57	55	51	46	7	1
Environmental sciences	595	560	489	460	408	400	366	361	6	7
Mathematical and computer sciences	477	460	415	345	305	289	274	253	4	9
Other sciences	724	738	636	593	494	449	365	348	–2	11
TOTAL	$9089	$8718	$7787	$7473	$6766	$6385	$5618	$5411	4%	8%
ANNUAL CHANGE	4%	12%	4%	10%	6%	14%	4%	13%		

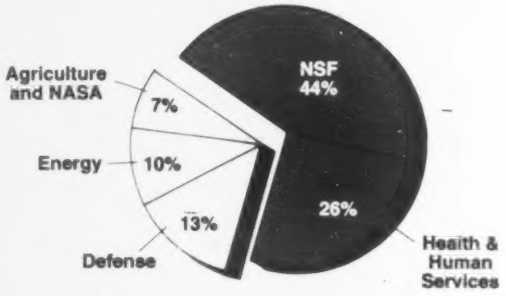
Note: Fiscal years. Includes funding only from six agencies that together represent about 96% of federal research support to universities. **a** Estimated. **Source:** National Science Foundation

UNIVERSITY RESEARCH IN CHEMISTRY: NSF and NASA grew strongly in 1992

Federal obligations, $ millions	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
NSF	$153.2	$138.3	$130.6	$118.5	$111.6	$107.1	$103.5	$108.1	11%	5%
Health & Human Services	91.5	85.1	79.9	76.5	91.4	85.0	75.0	75.2	8	4
National Institutes of Health	89.0	82.9	78.0	74.8	89.3	83.4	74.4	74.7	7	3
Alcohol, Drug Abuse & Mental Health Administration	2.5	2.2	1.9	1.6	2.1	1.6	0.6	0.6	14	33
Defense	46.9	47.0	41.9	42.0	41.3	45.0	43.2	40.4	0	2
Navy	19.1	17.7	16.2	14.3	13.6	17.2	13.9	15.5	8	3
Air Force	18.1	16.8	17.1	15.5	17.0	18.4	16.1	14.0	8	4
Army	6.5	6.2	5.8	7.7	8.8	[illegible]	12.4	10.9	5	–8
Defense agencies	3.2	6.3	2.8	4.4	1.8	1.1	0.9	0	–49	na
Energy	35.7	36.9	44.7	43.7	33.8	28.5	27.6	26.0	–3	5
Agriculture	16.3	16.4	14.4	11.8	11.8	11.2	12.2	15.5	–1	1
NASA	7.6	6.7	6.0	5.2	4.8	4.3	4.2	4.1	13	9
TOTAL	$351.2	$330.4	$317.5	$297.7	$294.7	$281.1	$265.7	$269.3	6%	4%
ANNUAL CHANGE	6%	4%	7%	1%	5%	6%	–1%	11%		

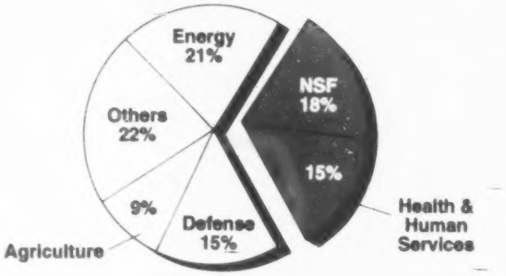
Note: Fiscal years. Data from these six agencies represent about 96% of federal obligations for fiscal 1992. **a** Estimated. **na** = not available. **Source:** National Science Foundation

Two agencies dominate federal funding for chemical research at universities . . .



Estimated fiscal 1992 federal obligations for university research in chemistry = $351 million[a]

. . . and provide just under a third of all chemical research funds

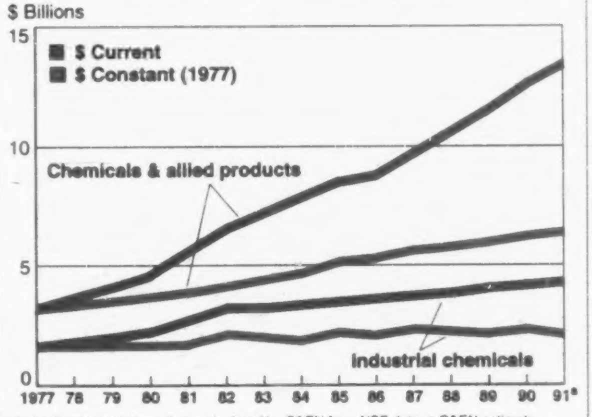


Estimated fiscal 1992 federal chemistry research obligations = $872 million

a Total is for these six agencies only. **Source:** National Science Foundation

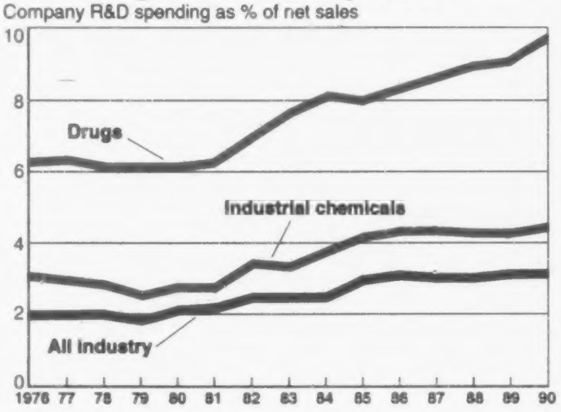
R&D Growth Eases Off in 1991

In constant dollars, R&D spending by industrial chemical firms slipped in '91



Note: Constant-dollar values calculated by C&EN from NSF data. a C&EN estimate.
Source: National Science Foundation

R&D's share of company revenue in all fields has grown since early 1980s



Source: National Science Foundation

TOTAL FUNDS FOR INDUSTRIAL R&D: Chemicals outpace other industries in 1991

$ Millions	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	% annual change 1990–91	% annual change 1981–91
Chemicals and allied products	$ 13,400[a]	$ 12,565	$ 11,466	$10,772	$ 9,878	$ 8,843	$ 8,540	$ 7,927	$ 7,185	$ 6,604	$ 5,625	7%	9%
Industrial chemicals	4,400[a]	4,344	4,039	3,959	3,901	3,552	3,498	3,240	3,214	3,206	2,802	1	5
Drugs	6,150[a]	5,654[a]	5,168[a]	4,746	4,158[a]	3,658	3,490[a]	3,316[a]	2,901[a]	2,481[a]	2,073[a]	9	12
Other chemicals	2,850[a]	2,567[a]	2,259[a]	2,067	1,819[a]	1,633	1,552[a]	1,371[a]	1,070[a]	917[a]	750[a]	11	14
Other Industries	**93,350[a]**	**91,779**	**90,388**	**87,117**	**82,277**	**78,980**	**75,699**	**66,873**	**58,083**	**52,046**	**46,185**	2	7
TOTAL	**$106,750[b]**	**$104,344**	**$101,854**	**$97,889**	**$92,155**	**$87,823**	**$84,239**	**$74,800**	**$65,268**	**$58,650**	**$51,810**	2%	8%

a C&EN estimates b Preliminary **Source:** National Science Foundation

COMPANY FUNDS FOR INDUSTRIAL R&D: Outlays for chemical R&D grew 10% in 1990

$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
Chemicals and allied products	$12,498	$11,383	$10,573	$ 9,445	$ 8,664	$ 8,310	$ 7,736	$ 6,792	$ 6,197	$ 5,205	$ 4,264	10%	11%
Industrial chemicals	4,280	3,960	3,763	3,531	3,374	3,281	3,057	2,828	2,810	2,393	1,856	8	9
Drugs	5,651	5,164	4,743	4,095	3,657	3,481	3,310	2,896	2,473	2,064	1,755[a]	9	12
Other chemicals	2,567	2,259	2,067	1,819	1,633	1,548	1,369	1,068	914	747	653	14	15
Other industries	**48,768**	**47,796**	**44,626**	**42,513**	**51,268**	**48,733**	**43,668**	**37,796**	**33,908**	**30,223**	**26,212**	2	6
TOTAL	**$73,764**	**$70,562**	**$65,772**	**$61,403**	**$59,932**	**$57,043**	**$51,404**	**$44,588**	**$40,105**	**$35,428**	**$30,476**	5%	9%

a C&EN estimates **Source:** National Science Foundation

FEDERAL FUNDS FOR INDUSTRIAL R&D: Chemical industry funds slashed in 1989 and 1990

												% annual change	
$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1989–90	1980–90
Chemicals and allied products	$ 67	$ 83	$ 199	$ 192	$ 179	$ 230	$ 191[a]	$ 393	$ 407	$ 421	$ 372	–19%	–16%[a]
Industrial chemicals	64	79	196	187	178	217	183[a]	386	396	409	341	–19	–15[a]
Drugs and other chemicals	3	4	3	5	1	13	8	7	11	12	31	–25	–21
Other industries	30,446	31,126	31,719	31,119	27,712	26,966	23,205	20,287	18,138	15,961	13,657	–2	9
TOTAL	$30,580	$31,292	$32,117	$31,311	$27,891	$27,196	$23,396	$20,680	$18,545	$16,382	$14,029	–2%	8%

[a] The decline in 1984 from 1983 results from the administration of federally funded Oak Ridge National Laboratory being changed from a chemical company to a company in the aircraft and missile industry. **Source:** National Science Foundation

R&D BY U.S. COMPANIES ABROAD: Funds spent by drug firms shot up 46% in 1990

												% annual change	
$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1989–90	1980–90
Chemicals and allied products	$2005	$1504	$1501	$1243	$1071	$ 843	$ 786	$ 729	$ 682	$ 715	$ 603	33%	13%
Industrial and other chemicals	549	508	781	625	579	444	385	368	319	287	246	8	8
Drugs	1456	996	720	618	492	399	401	361	363	428	357	46	15
Other industries	3800	5232	4794	3983	3553	2807	2847	2540	2412	2678	2562	–27	4
TOTAL	$7810	$6814	$6295	$5226	$4624	$3650	$3633	$3269	$3094	$3393	$3165	15%	10%

Source: National Science Foundation

R&D SPENDING: Chemical firms curbed spending in 1991, drug firms held strong

$ Millions	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1991 R&D spending as % of sales
CHEMICAL COMPANIES												
Du Pont	$1298	$1428	$1387	$1319	$1223	$1156	$1144	$1097	$ 966	$ 879	$ 718	3.4%
Dow Chemical	1159	1136	873	772	670	605	547	507	492	460	404	6.2
Monsanto	627	612	598	648	615	596	470	370	290	264	233	8.0
American Cyanamid	492	460	406	365	314	278	251	232	208	185	166	9.9
Union Carbide	190	191	181	159	159	148	275	265	245	240	207	3.2
Rohm & Haas	183	178	175	156	142	133	124	109	100	92	77	6.6
W. R. Grace	150	148	125	119	107	94	92	81	73	64	57	2.5
Hercules	86	92	79	74	74	71	76	72	74	74	65	2.9
Air Products[a]	80	72	71	72	57	61	51	44	40	37	32	2.7
Lubrizol	80	74	70	65	62	51	44	33	37	36	33	5.4
Ethyl	69[b]	65[b]	61[b]	59[b]	50	47	47	40	39	39	37	2.7
International Flavors	62	57	52	50	45	39	34	32	32	31	30	6.1
Morton International[c]	59	48	38	35	31	29	25	30	23	7	6	3.1
Nalco	47	45	41	37	35	33	32	32	30	33	30	3.8
Olin	41	66	66	58	62	56	53	52	49	45	38	1.8
Petrolite[d]	11	12	12	12	12	12	12	12	13	10	8	3.5
TOTAL	**$4634**	**$4684**	**$4235**	**$4000**	**$3658**	**$3409**	**$3277**	**$3008**	**$2711**	**$2496**	**$2141**	**4.3%**
ANNUAL CHANGE	**1%**	**11%**	**6%**	**9%**	**7%**	**4%**	**9%**	**11%**	**9%**	**17%**	**18%**	
PHARMACEUTICAL COMPANIES												
Merck & Co.	$ 998	$ 854	$ 751	$ 669	$ 566	$ 480	$ 426	$ 393	$ 356	$ 320	$ 274	11.6%
Bristol-Myers Squibb	993	881	789	688	563	474	412	344	301	260	226	8.9
Eli Lilly	767	703	605	512	466	427	370	341	294	267	235	13.4
Pfizer	757	640	531	473	401	336	287	255	230	199	179	10.9
Upjohn	491	427	407	380	356	314	284	247	218	185	162	14.4
Schering-Plough	426	380	327	298	251	212	175	164	145	127	109	11.8
TOTAL	**$4432**	**$3885**	**$3410**	**$3020**	**$2603**	**$2243**	**$1954**	**$1744**	**$1544**	**$1358**	**$1185**	**11.2%**
ANNUAL CHANGE	**14%**	**14%**	**13%**	**16%**	**16%**	**15%**	**12%**	**13%**	**14%**	**15%**	**15%**	

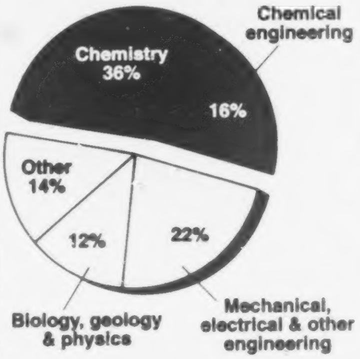
Note: Prior years are not restated to reflect company revisions. **a** For fiscal year ending Sept. 30. **b** Adjusted to reflect spin-off of Tredegar Industries. **c** For fiscal year ending June 30, includes all company-financed R&D but excludes contract R&D; data for Morton Thiokol prior to 1985. **d** For fiscal year ending Oct. 31. **Source:** Company data

CHEMISTS IN INDUSTRY: One fifth work in drug firms

Industry	% of industrial chemists: All chemists	B.S.	M.S.	Ph.D.	Mean salary ($ thousands)[a]: B.S.	M.S.	Ph.D.
MANUFACTURING							
Pharmaceuticals[b]	20%	16%	23%	22%	$45.0	$54.0	$74.8
Specialty chemicals	13	12	12	14	46.7	53.2	66.6
Basic chemicals	6	4	3	8	42.9	56.3	69.5
Plastics	5	4	4	6	47.5	57.4	70.8
Coatings	4	5	5	4	44.6	48.1	60.6
Petroleum and natural gas	4	4	3	5	47.7	57.8	75.6
Medical devices	3	2	3	4	40.0	56.4	66.6
Agricultural chemicals	3	3	3	4	39.9	50.4	67.9
Electronics	3	2	3	3	44.5	53.5	68.7
Food	3	4	4	2	41.6	55.1	68.2
Instruments	3	2	4	3	47.2	55.1	68.4
Aerospace	2	2	2	2	45.5	49.3	62.9
Rubber	2	3	2	1	46.6	45.7	62.1
Metals and minerals	2	2	2	1	41.8	48.6	62.8
Biochemical products	1	1	1	2	39.6	52.5	64.4
Soaps and detergents	1	2	1	1	39.9	55.6	69.8
Paper	1	1	1	2	42.6	52.4	63.1
Other	10	12	9	9	43.3	51.8	68.3
NONMANUFACTURING							
Analytical service labs	6	11	7	2	41.2	47.0	58.6
Contract research firms	3	2	2	4	43.0	52.0	59.8
Utilities	1	2	2	—	45.4	47.7	62.6
Other	4	6	5	3	46.2	54.9	62.6

a As of March 1, 1992; to facilitate comparison, mean salaries are adjusted for differences in average length of experience. b Includes personal care products. **Source:** ACS survey

Chemical fields draw 52% of industrial R&D professionals



Total R&D scientists and engineers in industry in 1991 = 709,700

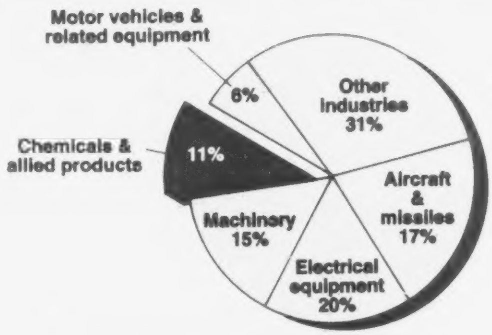
Note: Percentages represent distribution of scientists and engineers by area of work.
Source: Industrial Research Institute

R&D SCIENTISTS AND ENGINEERS IN INDUSTRY: Chemical firms up but total drops 3%

Thousands	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	% annual change: 1990–91	1981–91
Chemicals and allied products	**79.9**	**78.9**	**77.6**	**75.8**	**75.2**	**75.8**	**71.1**	**69.8**	**67.3**	**61.6**	**54.7**	1%	4%
Industrial chemicals	23.3[a]	23.0[a]	23.1[a]	22.5[a]	22.4[a]	24.9	23.5	25.6	26.6	25.9	21.6	1	1
Drugs	34.5	33.5	34.0	33.0	32.6	31.8	30.8	30.8[a]	28.2	25.6	23.3	3	4
Other chemicals	22.1	22.4	20.5	20.3	20.2	19.1	16.7	13.4	12.1	10.1	9.8	−1	9
Other industries	**629.8**	**652.0**	**642.6**	**632.8**	**620.6**	**595.2**	**551.4**	**514.3**	**473.6**	**448.2**	**433.1**	−3	4
TOTAL	**709.7**	**730.9**	**720.2**	**708.6**	**695.8**	**671.0**	**622.5**	**584.1**	**540.9**	**509.8**	**487.8**	−3%	4%

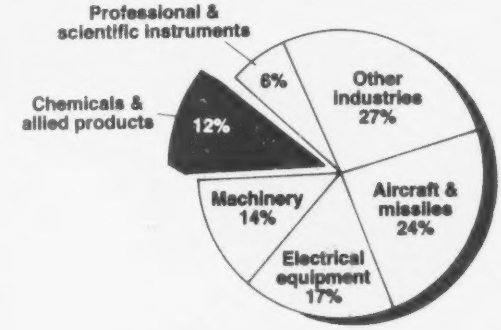
Note: Data as of January of each year for full-time equivalent personnel. a C&EN estimates. **Source:** National Science Foundation

Chemical producers employ 11% of industrial scientists and engineers . . .



1991 total industrial R&D scientists and engineers[a] = 709,700

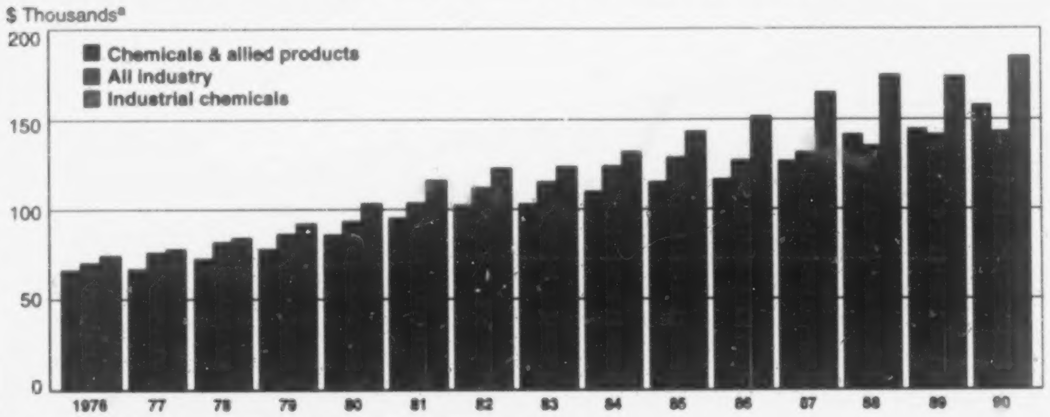
. . . and account for 12% of total industrial R&D spending in the U.S.



1990[b] total industrial R&D expenditures = $104 billion

a Data as of January 1991 for full-time equivalent personnel. b Latest year for which data are available. **Source:** National Science Foundation

Cost per R&D scientist is growing fastest in industrial chemical firms



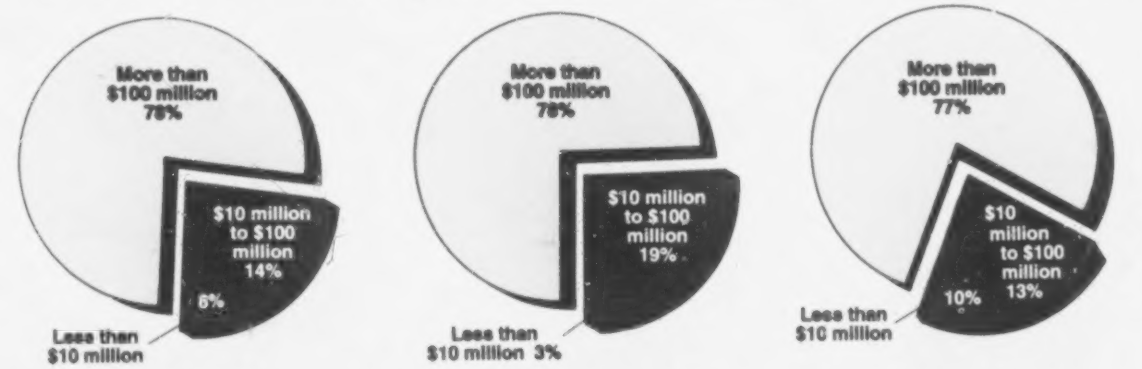
a Cost per industrial R&D scientist or engineer. **Source:** National Science Foundation

R&D SCIENTISTS AND ENGINEERS PER 1000 EMPLOYEES: Chemical firms up 76% since '80

Thousands	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
Chemicals and allied products	**74**	**72**	**70**	**68**	**70**	**57**	**57**	**54**	**51**	**44**	**42**
Industrial chemicals	57	56	55	52	56	39	41	45	44	37	36
Drugs	104	98	99	98	98	81	89	82	74	66	60
Other chemicals	64	63	61	61	63	62	51	39	37	33	30
All industry	**49**	**49**	**47**	**45**	**45**	**43**	**40**	**34**	**33**	**29**	**27**

Source: National Science Foundation

Chemical firms with research budgets under $100 million do more than a fifth of all R&D



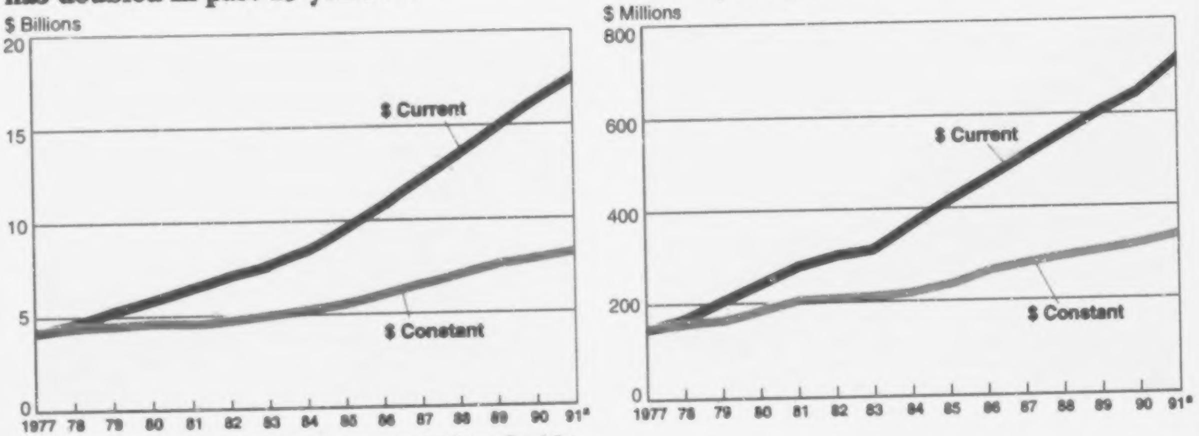
1990 chemicals and allied products R&D funds = $12.6 billion

1990 industrial chemicals R&D funds = $4.3 billion

1990 industry R&D funds = $104 billion

Note: Ranges indicate size of companies' 1990 R&D programs. **Source:** National Science Foundation

Academic R&D Outlays Top $16 Billion



In real terms, academic R&D spending has doubled in past 15 years . . .

. . . and spending for work in chemistry is up 116%

Note: Data for academic years. **a** C&EN estimates. **Source:** National Science Foundation

CHARACTER OF ACADEMIC R&D SPENDING: Basic research took 64% in 1990

$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
Basic research	$10,431	$ 9,710	$ 8,827	$ 8,398	$ 7,495	$6559	$5735	$5304	$4882	$4596	$4041	7%	10%
Applied research and development	5,894	5,299	4,637	3,756	3,431	3128	2882	2573	2441	2250	2035	11	11
TOTAL	**$16,325**	**$15,009**	**$13,464**	**$12,154**	**$10,926**	**$9687**	**$8617**	**$7877**	**$7323**	**$6846**	**$6077**	9%	10%
ANNUAL CHANGE	**9%**	**11%**	**11%**	**11%**	**13%**	**12%**	**9%**	**8%**	**7%**	**13%**	**13%**		

Note: Data for academic years **Source:** National Science Foundation

SOURCE OF ACADEMIC R&D FUNDS: Industry's share has almost doubled in 10 years

$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
Federal government	$ 9,611	$ 8,984	$ 8,181	$ 7,333	$ 6,703	$6057	$5424	$4983	$4763	$4565	$4104	7%	9%
Institutional funds	3,017	2,712	2,364	2,176	1,873	1622	1414	1303	1115	1008	837	11	14
State and local governments	1,338	1,234	1,107	1,024	916	754	690	626	616	546	496	8	10
Industry	1,135	998	871	789	699	559	475	388	337	291	236	15	17
Other sources	1,223	1,081	941	831	735	695	615	577	492	436	403	13	12
TOTAL	**$16,324**	**$15,009**	**$13,464**	**$12,153**	**$10,926**	**$9687**	**$8618**	**$7877**	**$7323**	**$6846**	**$6077**	9%	10%

Note: Data for academic years **Source:** National Science Foundation

FIELDS OF ACADEMIC R&D SPENDING: Chemical research accounts for 4%

$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
All sciences	$13,642	$12,606	$11,367	$10,262	$ 9,287	$8271	$7388	$6759	$6281	$5861	$5196	8%	10%
Life	8,763	8,088	7,256	6,533	5,893	5282	4713	4304	4016	3689	3218	8	11
Physical	1,781	1,641	1,545	1,389	1,286	1148	1000	900	823	765	678	9	10
Physics	834	774	730	665	630	551	474	417	367	357	322	8	10
Chemistry	649	608	565	513	469	421	371	335	308	285	245	7	10
Environmental	1,047	989	885	831	773	703	644	616	557	550	509	6	7
Psychology and social	962	875	767	690	633	541	504	481	484	494	453	10	8
Computer	503	468	410	373	323	283	225	187	149	132	114	7	16
Mathematical	221	215	199	177	152	128	123	106	96	87	79	3	11
Others	365	330	305	269	228	186	179	165	156	145	146	11	10
Engineering	2,682	2,404	2,097	1,892	1,638	1415	1229	1120	1041	968	866	12	12
Chemical	206	185	154	141	126	110	96	91	84	76	68	11	12
TOTAL	$16,342	$15,010	$13,464	$12,154	$10,925	$9686	$8617	$7879	$7322	$6829	$6062	9%	10%
ANNUAL CHANGE	9%	11%	11%	11%	13%	12%	9%	8%	7%	13%	13%		

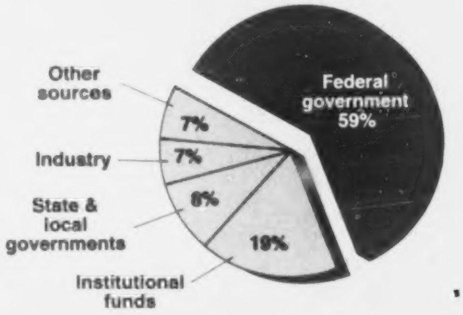
Note: Data for academic years. Data since 1981 were revised in 1989. **Source:** National Science Foundation

FEDERALLY FINANCED R&D SPENDING AT UNIVERSITIES: Growth slows for chemistry

$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
All sciences	$8076	$7601	$6951	$6220	$5727	$5192	$4637	$4249	$4059	$3898	$3500	6%	8%
Life	5068	4780	4318	3830	3489	3184	2827	2586	2502	2365	2094	6	9
Physical	1290	1193	1152	1046	982	890	782	699	650	619	555	8	8
Physics	647	598	574	530	510	453	390	343	307	309	280	8	9
Chemistry	443	422	403	368	338	313	279	247	230	217	190	4	9
Environmental	674	649	583	541	515	473	445	426	391	391	372	4	6
Psychology and social	394	368	329	292	287	260	241	236	250	280	263	7	4
Computer	334	318	289	257	233	196	163	139	107	93	77	5	16
Mathematical	159	156	149	131	114	97	92	76	72	68	61	2	10
Others	157	137	131	123	107	92	87	87	88	82	78	15	8
Engineering	1535	1385	1230	1112	976	865	787	733	703	662	596	11	10
Chemical	100	93	78	70	68	59	55	53	50	48	46	8	8
TOTAL	$9611	$8986	$8181	$7332	$6703	$6057	$5424	$4982	$4763	$4561	$4096	7%	9%
ANNUAL CHANGE	7%	10%	12%	9%	11%	12%	9%	5%	4%	11%	14%		

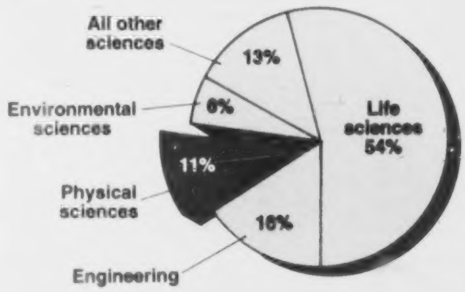
Note: Data for academic years. Data since 1981 were revised in 1989. **Source:** National Science Foundation

Federal government's share of all academic R&D slips below 60%



1990 academic R&D expenditures = $16.3 billion

Physical sciences claim about a tenth of academic R&D funds



1990 academic R&D expenditures = $16.3 billion

Source: National Science Foundation

TOP 10 UNIVERSITIES IN R&D SPENDING: Spending in life sciences dominates

Rank 1990	Rank 1989	$ Millions, 1990	Physical sciences	Chemistry[a]	Engineering	Environmental sciences	Life sciences	Math & computer sciences	Other sciences	Total
1	1	**Johns Hopkins U**	$ 93.4	$ 5.4	$ 204.8	$ 41.4	$ 208.6	$ 97.0	$ 23.9	**$ 669.1**
2	2	**Massachusetts Institute of Technology**	98.1	17.1	127.0	12.4	37.7	14.7	22.0	**311.9**
3	6	**U of Michigan**	15.3	3.7	53.9	17.2	162.4	10.1	51.7	**310.6**
4	5	**U of Wisconsin, Madison**	29.5	8.9	39.8	22.0	178.3	7.9	32.4	**309.9**
5	4	**Stanford U[b]**	53.8	10.8	83.7	5.6	138.5	16.6	7.3	**305.5**
6	3	**Cornell U**	44.9	10.0	39.7	6.2	166.6	27.1	15.6	**300.1**
7	6	**U of Minnesota**	16.6	6.7	27.9	8.8	204.6	16.4	17.6	**291.9**
8	8	**Texas A&M U**	17.5	8.0	62.8	64.0	106.9	5.5	16.1	**272.8**
9	11	**Pennsylvania State U**	16.6	9.1	118.1	14.1	83.7	3.6	20.8	**256.9**
10	9	**U of California, Los Angeles**	23.1	11.2	24.2	12.2	157.6	7.4	22.2	**246.7**
		TOTAL, FIRST 10 INSTITUTIONS	**$ 408.8**	**$ 90.9**	**$ 781.9**	**$ 204.0**	**$1444.9**	**$206.3**	**$ 229.6**	**$ 3,275.5**
		TOTAL, ALL INSTITUTIONS	**$1781.1**	**$649.4**	**$2681.8**	**$1047.3**	**$8763.5**	**$723.9**	**$1327.1**	**$16,324.7**

Note: Data for academic years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Comparing 1990 data with that reported in earlier years may be inappropriate in some areas. **a** Included in physical sciences. **b** Imputed.
Source: National Science Foundation

TOP 10 UNIVERSITY R&D CENTERS: Physical sciences get almost 40% of federal support

$ Millions, 1990	Physical sciences	Engineering	Math & computer sciences	Environmental sciences	Life sciences	Psychology & social sciences	Other sciences	Total
1 Jet Propulsion Lab	$ 76.1	$ 401.1	$499.3	$ 89.3	$ 0	$ 0	$ 0	**$1065.8**
2 Lawrence Livermore National Lab	315.5	487.5	152.7	33.3	30.9	0	0	**1019.9**
3 Los Alamos National Lab	443.1	316.4	91.8	6.4	33.0	29.0	6.4	**926.1**
4 Lincoln Lab	79.9	295.4	43.4	0	0	0.4	0	**419.1**
5 Argonne National Lab	90.1	163.1	5.0	75.5	13.9	0	0	**347.6**
6 Brookhaven National Lab	193.7	38.8	0.6	8.7	21.3	0.5	0.2	**263.8**
7 Lawrence Berkeley Lab	139.5	1.1	1.9	11.0	36.4	0	6.1	**196.0**
8 Fermi National Accelerator Lab	184.6	0	0	0	0	0	0	**184.6**
9 Stanford Linear Accelerator Center	115.2	0	0	0	0	0	0	**115.2**
10 Plasma Physics Lab	95.3	0	0	0	0	0	0	**95.3**
Eight others	90.7	4.6	26.7	67.8	6.8	0.2	0	**196.8**
TOTAL, TOP 18 FEDERALLY FUNDED R&D CENTERS	**$1823.7**	**$1708.0**	**$821.4**	**$292.0**	**$142.3**	**$29.7**	**$12.7**	**$4830.2**

Note: Data for university-administered, federally funded R&D centers. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Comparing 1990 data with those reported in earlier years may be inappropriate in some areas.
Source: National Science Foundation

UNIVERSITY SPENDING FOR RESEARCH EQUIPMENT: Government provides 60% of the funds

	1990		1989		1983		% annual change			
							1989–90		1983–90	
$ Millions	Total	Federal funds	Total	Federal funds	Total	Federal funds	Total	Federal funds	Total	Federal funds
All sciences	**$ 794.1**	**$470.2**	**$789.0**	**$474.7**	**$374.4**	**$228.7**	**1%**	**1%**	**8%**	**7%**
Life sciences	**430.3**	**224.9**	**440.0**	**237.6**	**211.3**	**115.0**	**–2**	**–5**	**7**	**7**
Physical sciences	**187.7**	**140.6**	**179.7**	**132.4**	**81.0**	**63.6**	**4**	**6**	**8**	**8**
Physics	89.6	73.1	82.0	64.5	36.7	30.6	9	13	9	9
Chemistry	72.7	51.2	75.4	52.6	32.6	23.2	–4	–3	8	8
Environmental sciences	**69.9**	**46.2**	**65.4**	**43.9**	**31.1**	**19.2**	**7**	**5**	**8**	**9**
Mathematical and computer sciences	**54.8**	**35.0**	**52.5**	**35.9**	**24.6**	**17.0**	**4**	**–3**	**8**	**7**
Other sciences	**51.4**	**23.5**	**51.4**	**24.9**	**26.4**	**13.9**	**0**	**–6**	**7**	**5**
Engineering	**219.5**	**124.9**	**205.2**	**117.4**	**79.9**	**51.9**	**7**	**6**	**11**	**8**
Chemical	17.2	7.8	18.6	9.4	6.0	3.5	–8	–17	11	8
TOTAL	**$1013.6**	**$595.1**	**$994.2**	**$592.1**	**$454.3**	**$280.6**	**2%**	**0%**	**8%**	**8%**

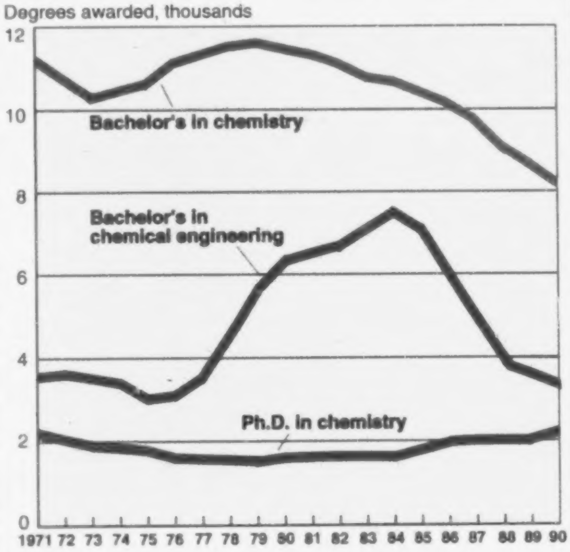
Note: Data for academic years. **Source:** National Science Foundation

CHEMICAL DEGREES: Only Ph.D. chemists posted gains in 1990

Academic year	Degrees awarded in chemistry: Bachelor's	Master's	Ph.D.	Degrees awarded in chemical engineering: Bachelor's	Master's	Ph.D.
1971	11,183	2284	2160	3615	1100	406
1972	10,721	2259	1971	3663	1154	394
1973	10,226	2230	1882	3636	1051	397
1974	10,525	2138	1828	3454	1045	400
1975	10,649	2006	1824	3142	990	346
1976	11,107	1796	1623	3203	1031	308
1977	11,322	1775	1571	3581	1086	291
1978	11,474	1892	1525	4615	1237	259
1979	11,643	1765	1518	5655	1149	304
1980	11,446	1733	1551	6383	1271	284
1981	11,347	1654	1622	6527	1267	300
1982	11,062	1751	1722	6740	1285	311
1983	10,746	1604	1746	7145	1304	319
1984	10,704	1667	1744	7475	1514	330
1985	10,482	1719	1789	7146	1544	418
1986	10,116	1754	1908	5877	1361	446
1987	9,661	1738	1976	4983	1184	497
1988	9,052	1708	1995	3917	1088	579
1989	8,654	1785	2034	3684	1097	599
1990	8,126	1696	2183	3450	1030	564

Source: National Center for Education Statistics

Bachelor's degrees continue to decline



Note: Academic years. **Source:** National Center for Education Statistics

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POSTDOCTORAL APPOINTEES: Chemistry, biochemistry account for 29% of all in sciences

	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
All sciences	**20,444**	**19,321**	**18,182**	**17,469**	**16,591**	**15,628**	**15,017**	**14,598**	**13,694**	**13,742**	**13,035**	**6%**	**5%**
Biological sciences	**12,498**	**11,723**	**10,885**	**10,515**	**9,816**	**9,226**	**8,758**	**8,404**	**7,756**	**7,707**	**7,106**	7	6
Biochemistry	2,319	2,244	2,090	2,121	1,989	1,866	1,789	1,750	1,684	1,724	1,599	3	4
Physical sciences	**5,545**	**5,355**	**5,187**	**4,953**	**4,843**	**4,517**	**4,386**	**4,444**	**4,281**	**4,462**	**4,264**	4	3
Chemistry	3,610	3,462	3,429	3,246	3,151	2,995	2,906	2,973	2,805	2,870	2,710	4	3
Physics	1,721	1,678	1,578	1,548	1,527	1,342	1,320	1,350	1,326	1,445	1,398	3	2
Psychology and social sciences	**967**	**916**	**818**	**839**	**852**	**853**	**761**	**788**	**803**	**803**	**913**	6	1
Earth, atmospheric, and ocean sciences	**611**	**459**	**499**	**420**	**417**	**375**	**488**	**415**	**335**	**339**	**308**	33	7
Agricultural sciences	**499**	**477**	**422**	**414**	**388**	**357**	**358**	**295**	**279**	**284**	**239**	5	8
Mathematical and computer sciences	**324**	**301**	**271**	**328**	**275**	**300**	**266**	**252**	**240**	**147**	**205**	8	5
Engineering	**1,953**	**1,914**	**1,684**	**1,442**	**1,398**	**1,347**	**1,194**	**1,101**	**978**	**1,040**	**978**	2	7
Chemical	551	466	423	310	295	273	245	198	174	171	183	13	12
Metallurgical and materials	368	323	325	282	249	245	168	204	166	193	172	14	8
TOTAL	**22,397**	**21,145**	**19,866**	**18,911**	**17,989**	**16,975**	**16,211**	**15,699**	**14,672**	**14,782**	**14,013**	**6%**	**5%**
ANNUAL CHANGE	**6%**	**6%**	**5%**	**5%**	**6%**	**5%**	**3%**	**7%**	**–1%**	**5%**	**–**		

Source: National Science Foundation

SCHOOLS SPENDING MOST ON CHEMICAL R&D: Top 10 account for almost 20% of total

Rank 1990	Rank 1989		1990 Total spending ($ thousands)	1990 % federal funds	1989 ($ thousands)	1988 ($ thousands)	1987 ($ thousands)	1986 ($ thousands)	1985 ($ thousands)	% annual change 1989–90	% annual change 1985–90
1	1	**Massachusetts Inst. of Technology**	$ 17,109	88%	$ 15,031	$ 13,287	$ 11,471	$ 13,593	$ 13,221	14%	5%
2	2	**U of California, Berkeley**	13,804	88	12,663	14,285	12,490	9,114	10,804	9	5
3	4	**U of Texas, Austin**	13,259	51	11,484	10,943	11,420	8,531	7,908[a]	15	11
4	3	**Harvard U**	13,114	90	11,856	9,886	8,895	7,202	6,557	11	15
5	7	**U of California, Los Angeles**	11,217	91	9,855	9,519	10,099	7,954	7,243	14	9
6	9	**U of Maryland, College Park**	10,977	43	9,732	8,545	9,258	7,904	7,289	13	9
7	6	**Stanford U**	10,752[b]	87	10,098	10,547	8,916	8,340	8,354	7	5
8	11	**California Inst. of Technology**	10,667	81	9,235	9,931	10,870	9,176	7,605	6	7
9	5	**Cornell U**	10,042	72	10,217	10,472	8,397	7,376[a]	7,962[a]	−2	5
10	10	**U of Chicago**	9,331	91	9,333	8,046	7,514	7,553	6,921	0	6
		Total, first 10 institutions	$120,272	79%	$109,504	$105,461	$ 99,330	$ 86,743	$ 83,864	10%	8%
11	22	**Rockefeller U**	9,248	47	7,471	6,975	6,823	7,335	11,826	24	9
12	73	**U of Massachusetts**	9,245	59	2,988	5,280	7,589	6,967	6,420	209	8
13	12	**U of Illinois, Urbana**	9,243	71	9,208	8,647	9,035	8,604	7,079	0	5
14	15	**Pennsylvania State U**	9,148	30	8,616	7,739	6,072	6,438	6,509	6	7
15	13	**Princeton U**	9,099	68	8,873	8,087	6,477	5,702	3,963	2	18
16	16	**U of Wisconsin, Madison**	8,937	61	8,326	7,282	6,984	7,892	7,350	7	4
17	14	**Purdue U**	8,672	79	8,769	8,615	7,092	6,315[a]	6,018	−1	8
18	17	**Case Western Reserve U**	8,252[a]	51	8,233	7,996	7,164	2,922	2,802	0	24
19	27	**U of California, San Diego**	8,120	91	6,487	6,780	5,179	6,535	4,642	25	12
20	20	**U of Pennsylvania**	8,077	91	7,760	7,292	6,741	6,064	5,025	4	10
		Total, first 20 institutions	$208,313	75%	$186,235	$180,154	$168,486	$151,526	$138,498	12%	9%
21	8	**Texas A&M U**	8,046	46	9,808	8,785	7,462	7,230[a]	6,768[a]	−18	
22	36	**Arizona State U**	7,967	46	5,260	4,306	3,586	4,124	2,703	51	24
23	19	**Rutgers U**	7,812	84	7,905	5,926	3,913	3,507	2,368	−1	5
24	18	**Indiana U**	7,344	83	7,927	7,991	6,181	6,110	5,820	−7	7
25	21	**Northwestern U**	7,219	76	7,661	6,644	6,095	4,826	5,062	−6	8
26	33	**U of Oregon**	6,760	77	5,501	5,650	4,462	5,087	4,640	23	10
27	29	**U of Minnesota**	6,663	88	5,863	5,232	5,426	5,110	4,167	14	10
28	46	**U of Rochester**	6,537	92	4,762	4,437	3,545	3,584	3,196	37	15
29	25	**U of Notre Dame**	6,348	89	6,660	7,004	5,550	5,402	5,549	−5	3
30	39	**Virginia Polytechnic Inst. & State U**	6,321	40	5,155	4,735	4,190	3,786	4,840	23	5
		Total, first 30 institutions	$279,330	73%	$252,737	$240,764	$218,896	$200,292	$183,611	11%	9%
31	24	**Ohio State U**	6,225	66	6,771	7,568	5,755	6,546	5,422	−8	3
32	37	**U of Washington**	6,057	68	5,192	4,338	3,655	2,971	2,964	17	15
33	26	**U of Colorado**	6,041	86	6,587	5,637	5,118	6,535	4,642	−8	5
34	28	**Yale U**	6,037	87	5,915	6,869[a]	5,538	5,110	4,167	2	8
35	23	**Columbia U, main division**	5,858	96	4,721[a]	4,605	6,715	5,555	5,138	24	5
36	30	**U of Pittsburgh**	5,832	81	5,736	5,598	5,105	4,974	4,580	2	5
37	53	**U of Southern California**	5,667	96	4,374	3,832	3,311	3,164	2,463	30	18
38	32	**Wayne State U**	5,455	33	5,557	4,582	3,278	3,405	2,903	−2	13
39	44	**U of Kansas**	5,450	38	4,952	3,845	2,803	1,808	1,875[b]	10	24
40	40	**Johns Hopkins U**	5,435	92	5,152	5,211	5,593	5,506	4,650[a]	5	3
		Total, first 40 institutions	$337,387	73%	$307,694	$292,849	$265,767	$245,866	$222,467	10%	9%
41	42	**U of Florida**	5,396	54	5,061	5,030	5,690	4,750	4,380	7	4
42	34	**Florida State U**	5,345	25	5,382	4,308	3,841	4,047	3,276	−1	10
43	38	**U of North Carolina, Chapel Hill**	5,310	87	5,171	4,476	3,471	3,352	3,386	3	9
44	41	**U of Virginia**	5,281	76	5,096	4,153	4,169	3,436	3,046	4	12
45	35	**Georgia Inst. of Technology**	5,215	56	5,380	5,989	4,889	5,260	3,684	−3	7
46	31	**U of Utah**	5,089	74	5,653	4,600	4,846	5,354	4,840	−10	1
47	51	**U of Arizona**	5,034	64	4,532	3,934	3,441	3,016	2,217	11	18
48	47	**State U of New York, Stony Brook**	4,897	78	4,754	5,010	3,669	3,333	3,481	3	7
49	60	**U of California, Irvine**	4,835	92	3,910	4,534	3,541	3,486	5,877	24	−4
50	50	**State U of New York, Buffalo**	4,770	62	4,644	3,903	3,370	2,837	2,768	3	11
		Total, first 50 institutions	$388,559	73%	$357,277	$338,786	$306,694	$284,737	$259,422	9%	8%
		NATIONAL TOTAL	$649,432	68%	$608,029	$565,293	$513,116	$469,275	$421,506	7%	9%

Note: Data for academic fiscal years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Comparing 1990 data with those reported in earlier years may be inappropriate in some areas. Data for 1986 and later were revised in 1989. **a** Estimate. **b** Imputed. **Source:** National Science Foundation

SCHOOLS WITH MOST FEDERAL SUPPORT FOR CHEMICAL R&D: **Top 10 receive 22%**

Rank			1990	1989	1988	1987	1986	1985	% annual change	
1990	1989		($ thousands)						1989–90	1985–90
1	1	**Massachusetts Inst. of Technology**	$ 15,129	$ 13,333	$ 11,987	$ 10,656	$ 12,909	$ 12,424	13%	4%
2	2	**U of California, Berkeley**	12,219	11,450	12,998	11,160	8,258	9,892	7	4
3	3	**Harvard U**	11,855	10,594	9,272	8,309	6,748	6,557	12	13
4	4	**U of California, Los Angeles**	10,216	9,024	8,885	9,414	7,516	6,389	13	10
5	5	**Stanford U**	9,355[a]	8,878	9,423	7,918	7,524	7,097	5	6
6	7	**California Inst. of Technology**	8,629	7,459	8,769	9,922	7,612	7,001	16	4
7	6	**U of Chicago**	8,524	8,621	7,235	6,499	6,799[a]	6,265[a]	–1	6
8	18	**U of California, San Diego**	7,422	5,757	6,161	4,599	5,918	4,053	29	13
9	10	**U of Pennsylvania**	7,330	7,046	6,337	5,653	5,232	4,938	4	8
10	8	**Cornell U**	7,211	7,458	8,269	6,753	5,934	6,293	–3	3
		Total, first 10 institutions	$ 97,890	$ 89,619	$ 89,376	$ 80,883	$ 74,450	$ 70,909	9%	7%
11	9	**Purdue U**	6,893	7,102	7,120	5,978	5,708	5,418	–3	5
12	16	**U of Texas, Austin**	6,723	6,120	6,443	6,405	4,922	4,741	10	7
13	13	**U of Illinois, Urbana**	6,563	6,566	6,193	6,306	5,999	5,371	0	4
14	14	**Pennsylvania State U**	6,429	6,515	5,957	4,915	5,161	5,860	–1	2
15	19	**Princeton U**	6,104	5,681	5,812	5,064	4,575	3,104	7	14
16	21	**U of Wisconsin, Madison**	6,041	5,505	4,939	4,718	5,348	5,156	10	3
17	12	**Rutgers U**	6,016	6,572	3,442	2,525	2,123	2,055	–8	24
18	32	**U of Rochester**	5,998	4,327	3,936	3,275	3,336	2,861	37	16
19	24	**U of Minnesota**	5,857	5,054	4,156	4,395	4,013	2,255	16	21
20	17	**U of Notre Dame**	5,667	5,983	6,557	5,158	4,998	5,097	–5	2
		Total, first 20 institutions	$160,181	$149,044	$143,931	$129,622	$120,663	$112,827	7%	7%
21	11	**Columbia U, main division**	5,540	4,344[b]	4,246[b]	6,625	5,030	4,490	27	4
22	87	**U of Massachusetts**	5,494	1,326	3,296	5,036	4,411	4,091	314	33
23	20	**Northwestern U**	5,465	5,577	4,955	4,641	3,753	3,963	–2	7
24	34	**U of Southern California**	5,358	3,986	3,568	2,903	2,857	2,149	34	20
25	25	**Yale U**	5,256	5,011	5,927	4,909	5,566[b]	5,095[b]	5	1
26	15	**Indiana U**	5,225	6,127	6,354	4,923	4,757	4,885	–15	1
27	22	**U of Colorado**	5,218	5,418	4,603	4,402	4,811	5,430	–4	–1
28	30	**U of Oregon**	5,182	4,435	4,519	3,579	4,345	3,959	17	6
29	26	**Johns Hopkins U**	4,994	4,824	4,830	5,116	4,903	4,155	4	4
30	36	**U of Maryland, College Park**	4,774	3,844	3,793	4,073	3,557	3,323	24	8
		Total, first 30 institutions	$212,687	$193,926	$190,022	$175,829	$164,653	$154,367	10%	7%
31	27	**U of Pittsburgh**	4,721	4,558	4,803	4,028	4,045	3,836	3	4
32	28	**U of North Carolina, Chapel Hill**	4,651	4,534	4,193	3,153	2,929	2,885	3	10
33	39	**U of California, Irvine**	4,437	3,685	4,376	3,386	3,394	3,035	20	8
34	38	**Rockefeller U**	4,331	3,713	3,082	3,247	3,377	2,553	17	11
35	23	**Case Western Reserve U**	4,246	5,161	5,433	5,016	2,062	2,065	–18	16
36	37	**U of Washington**	4,139	3,756	2,904	2,287	1,898	1,738	10	19
37	29	**Ohio State U**	4,085	4,445	5,437	4,517	4,931	3,846	–8	1
38	33	**U of Virginia**	4,038	4,165	3,419	3,281	2,748	2,165	–3	13
39	61	**U of Alabama, Huntsville**	3,880	2,414	1,059	781[b]	463	na	61	na
40	43	**U of California, Santa Barbara**	3,869	3,242	3,196	3,526	3,087	2,709	19	7
		Total, first 40 institutions	$255,084	$229,213	$227,924	$209,051	$193,587	$179,202	11%	7%
41	40	**State U of New York, Stony Brook**	3,816	3,610	3,460	2,930	2,168[b]	2,343	6	10
42	35	**U of Utah**	3,746	3,872	3,614	4,194	4,791	4,426	–3	–3
43	31	**Texas A&M U**	3,716	4,408	4,945	4,019	3,129	4,195	–16	–3
44	44	**Arizona State U**	3,626	3,172	2,813	2,317	2,218	2,306	14	10
45	58	**Emory U**	3,509	2,719	2,362	2,093	2,163	1,184	29	24
46	47	**U of Arizona**	3,210	3,044	2,885	2,499	2,291	1,738	5	13
47	45	**Georgetown U**	3,088	3,113	2,148	2,155	2,252	1,075	–1	23
48	42	**U of California, Davis**	2,996	3,386	2,255	1,980	2,175	1,702	–12	12
49	54	**U of South Carolina**	2,992	2,905	2,839	3,113	3,285	2,787	3	1
50	63	**U of Iowa**	2,929	2,364	1,718	1,846	1,545	1,511	24	14
		Total, first 50 institutions	$288,712	$260,517	$256,963	$236,197	$219,604	$202,469	11%	8%
		NATIONAL TOTAL	$443,402	$421,711	$402,724	$367,765	$338,027	$312,831	5%	7%

Note: Data for institutional fiscal years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Comparing 1990 data with those reported in earlier years may be inappropriate in some areas. Data for 1986 and later were revised in 1989. **a** Imputed. **b** Estimated. **na**=not available. **Source:** National Science Foundation

SCHOOLS SPENDING MOST ON CHEMICAL ENGINEERING R&D: MIT retains lead

Rank 1990	Rank 1989		Chemical engineering: Total spending ($ thousands)	Chemical engineering: Federal funds	Chemical engineering: % federal funds	All engineering: Total spending ($ thousands)	All engineering: Federal funds	All engineering: % federal funds
1	1	**Massachusetts Inst. of Technology**	$ 13,456	$ 9,279	69%	$ 127,004	$ 85,559	67%
2	2	**U of Minnesota**	7,817	5,249	67	27,943	10,781	39
3	3	**U of Texas, Austin**	6,025	2,388	40	58,968	26,031	44
4	8	**Texas A&M U**	6,017	922	15	62,791	13,388	21
5	24	**Georgia Inst. of Technology**	5,382	3,035	56	116,867	65,901	56
6	6	**U of Maryland, College Park**	4,941	1,577	32	43,964	16,336	37
7	5	**Johns Hopkins U**	4,580	4,171	91	204,793	200,964	98
8	11	**North Carolina State U, Raleigh**	4,421	1,764	40	40,181	15,077	37
9	9	**U of Wisconsin, Madison**	4,363	2,407	55	39,781	24,474	61
10	4	**Columbia U, main division**	4,262	2,265	53	17,647	11,777	67
		Total, first 10 institutions	$ 61,264	$33,057	54%	$ 739,939	$ 470,288	64%
11	75	**Oklahoma, State U**	4,028	2,660	66	15,639	6,931	44
12	12	**U of Delaware**	3,826	1,140	30	12,251	4,305	35
13	10	**Case Western Reserve U**	3,665[a]	2,004	55	19,049[a]	12,638	66
14	20	**Auburn U**	3,259	935	29	18,819	5,017	27
15	13	**Stanford U**[b]	3,130	2,701	86	83,694	69,015	82
16	15	**Lehigh U**	3,067	555	18	19,596	7,353	37
17	18	**Princeton U**	2,981	1,281	43	23,048	11,931	52
18	17	**U of Houston**	2,870	1,009	35	8,027	2,754	34
19	30	**Louisiana State U**	2,714	872	22	20,890	8,345	40
20	21	**U of Michigan**	2,668	1,686	63	53,905	31,447	58
		Total, first 20 institutions	$ 93,472	$47,900	51%	$1,014,857	$ 630,024	62%
21	45	**Arizona State U**	2,644	614	23	18,618	4,933	26
22	53	**U of Utah**	2,554	1,120	44	16,502	7,872	48
23	16	**Pennsylvania State U**	2,430	724	30	118,070	74,737	63
24	32	**Virginia Polytechnic Inst. & State U**	2,320	878	38	44,473	22,304	50
25	33	**U of California, Santa Barbara**	2,280	1,764	77	22,214	18,807	85
26	29	**New Mexico Inst. of Mining & Tech.**	2,259	408	18	16,090	2,519	16
27	22	**Cornell U**	2,233	1,340	60	39,663	22,780	57
28	35	**State U of New York, Buffalo**	2,224	1,139	51	23,166	7,900	34
29	28	**U of Washington**	2,133	1,020	48	16,985	11,359	67
30	27	**Rutgers U**	2,133	755	35	21,694	4,262	20
		Total, first 30 institutions	$114,449	$57,662	50%	$1,352,332	$ 807,497	60%
		NATIONAL TOTAL	$206,172	$99,937	48%	$2,681,751	$1,534,931	57%

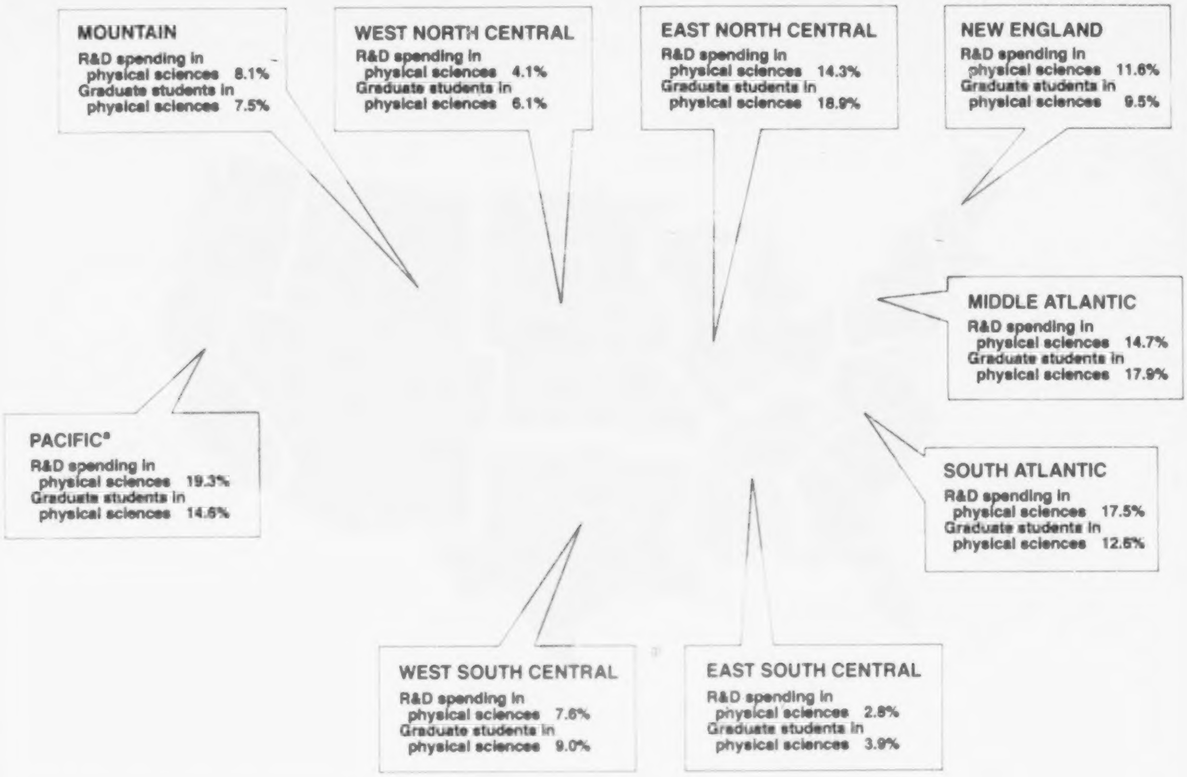
Note: Data for 1990 academic year. a Estimated. b Imputed. **Source:** National Science Foundation

FOREIGN GRADUATE STUDENTS: They now represent more than one fifth of total

	1990		1989		1988		1987[a]		1986[a]		1985[a]		% annual change	
	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	1989–90	1985–95
All sciences	55.9	19%	53.2	19%	51.2	19%	48.2	18%	45.5	17%	41.8	16%	5%	6%
Psychology and social sciences	14.5	11	14.1	12	14.2	12	13.5	12	13.1	12	12.5	11	3	3
Mathematical and computer sciences	13.7	25	13.0	25	12.6	24	12.0	24	11.3	23	10.4	22	5	6
Physical sciences	11.7	34	11.1	33	10.5	32	10.0	31	9.5	29	8.5	27	5	7
Chemistry	6.1	32	5.7	30	5.3	28	4.9	26	4.5	24	4.1	22	7	8
Physics	5.4	39	5.2	38	5.0	38	4.9	37	4.8	39	4.2	36	4	5
Biological sciences	10.8	21	10.1	20	9.1	19	8.1	17	7.2	15	6.4	14	7	11
Biochemistry	1.6	31	1.5	29	1.3	26	1.2	25	1.1	22	1.0	21	7	10
Agricultural sciences	2.7	24	2.6	24	2.6	24	2.6	24	2.5	22	2.3	20	4	3
Earth, atmospheric, and ocean sciences	2.5	18	2.3	17	2.2	16	2.0	4	1.9	13	1.7	11	9	8
Engineering	31.3	29	30.4	29	29.6	28	28.1	27	27.1	26	24.1	25	3	5
Chemical	2.8	42	2.6	40	2.4	36	2.3	32	2.2	31	2.2	31	8	5
Metallurgical and materials	1.8	38	1.8	40	1.6	37	1.6	37	1.5	36	1.3	36	0	7
TOTAL	87.2	22%	83.6	22%	80.8	21%	76.3	20%	72.6	20%	65.9	18%	4%	6%
ANNUAL CHANGE	4%		3%		6%		5%		10%		7%			

Note: The percent of total is the percent of all full-time graduate students in each area who are foreign. a Includes estimated data for master's-granting institutions, which were surveyed on a sample basis from 1984 through 1987. **Source:** National Science Foundation

Schools east of Mississippi River get 61% of R&D funds, 63% of grad students


MOUNTAIN
R&D spending in physical sciences 8.1%
Graduate students in physical sciences 7.5%
WEST NORTH CENTRAL
R&D spending in physical sciences 4.1%
Graduate students in physical sciences 6.1%
EAST NORTH CENTRAL
R&D spending in physical sciences 14.3%
Graduate students in physical sciences 18.9%
NEW ENGLAND
R&D spending in physical sciences 11.6%
Graduate students in physical sciences 9.5%
MIDDLE ATLANTIC
R&D spending in physical sciences 14.7%
Graduate students in physical sciences 17.9%
PACIFIC[a]
R&D spending in physical sciences 19.3%
Graduate students in physical sciences 14.6%
SOUTH ATLANTIC
R&D spending in physical sciences 17.5%
Graduate students in physical sciences 12.6%
WEST SOUTH CENTRAL
R&D spending in physical sciences 7.6%
Graduate students in physical sciences 9.0%
EAST SOUTH CENTRAL
R&D spending in physical sciences 2.8%
Graduate students in physical sciences 3.9%

Key to map: Using the Middle Atlantic states as an example, 14.7% of all R&D expenditures in the physical sciences and 17.9% of all graduate students in physical sciences are in this area. The figures for funding apply to Ph.D.-granting universities and colleges only. The figures for students apply to all universities and colleges.

Note: Data are based on $1.7 billion of R&D expenditures and 34,197 graduate students in the physical sciences enrolled in colleges and universities during the 1990 academic year. a Includes Alaska and Hawaii. **Source:** National Science Foundation

GRADUATE SCIENCE STUDENTS: Modest growth for chemistry, chemical engineering

												% annual change	
Thousands	1990	1989	1988	1987[a]	1986[a]	1985[a]	1984[a]	1983	1982	1981	1980	1989–90	1980–90
All sciences	292.3	281.1	274.4	271.0	267.4	263.8	258.5	257.6	256.1	254.4	265.7	4%	2%
Psychology and social sciences	127.3	120.9	116.2	114.6	112.0	111.9	111.2	113.2	117.1	120.3	130.4	5	–1
Biological sciences	50.9	49.6	48.3	47.5	47.2	46.5	46.2	46.1	46.3	47.0	47.9	3	1
Biochemistry	5.2	5.2	5.0	4.8	4.9	4.7	4.5	4.2	4.1	4.1	4.1	0	5
Mathematical and computer sciences	54.4	52.2	51.9	50.7	49.4	47.5	43.3	41.0	37.0	32.4	28.9	4	7
Physical sciences	34.3	33.6	33.0	32.7	32.3	31.0	30.1	29.5	28.2	28.2	27.0	2	2
Chemistry	19.1	18.8	18.6	18.8	18.7	18.3	17.8	17.8	17.0	16.3	16.2	2	2
Physics	14.0	13.7	13.3	12.8	12.4	11.7	11.3	10.8	10.3	10.2	10.0	2	3
Earth, atmospheric, and ocean sciences	14.2	13.8	14.0	14.5	15.2	15.5	15.6	15.5	15.2	14.4	14.2	3	0
Agricultural sciences	11.2	11.0	11.0	11.0	11.3	11.4	12.1	12.3	12.3	12.1	12.3	2	–1
Engineering	109.3	104.8	103.7	104.6	103.1	97.0	93.6	91.9	84.6	80.5	75.1	4	4
Chemical	6.7	6.5	6.6	7.1	7.0	7.2	7.4	7.6	7.2	6.5	6.0	3	1
Metallurgical and materials	4.8	4.5	4.3	4.3	4.2	3.9	3.7	3.4	3.1	3.1	2.9	7	5
Petroleum	0.7	0.7	0.7	0.8	0.7	0.8	0.7	0.7	0.6	0.5	0.5	0	3
TOTAL	401.6	385.9	378.1	375.6	370.5	360.8	352.1	349.5	340.7	334.9	340.8	4%	2%
ANNUAL CHANGE	4%	2%	1%	1%	3%	2%	1%	3%	2%	–2%	4%		

Note: Data for all institutions. Data for 1981 and later were revised in 1990. a Includes estimated data for master's-granting institutions, which were surveyed on a sample basis from 1984 through 1987. **Source:** National Science Foundation

U.S. Continues To Lead In Global R&D

WORLDWIDE R&D SCIENTISTS AND ENGINEERS: U.S. has more than twice as many as Japan . . .

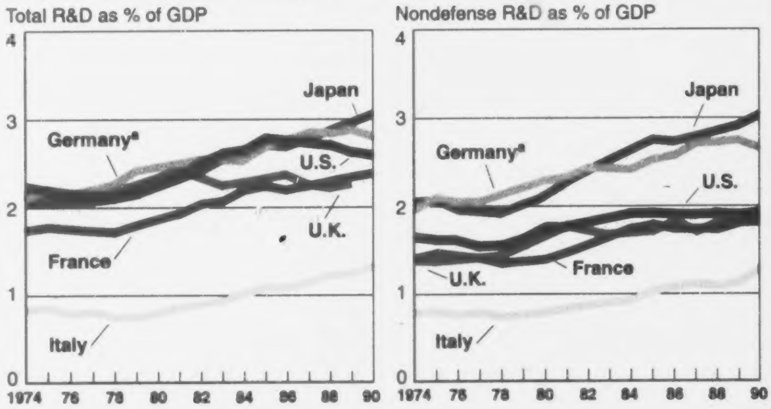
Thousands	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	% annual change[a] 1979–89	% annual change[a] 1988–89
U.S.	na	949	927	910	882	841	798	752	712	683	651	615	2%	4%
Japan[b]	482	462	442	418	406	381	370	342	330	318	303	282	4	5
Germany[c]	na	176	na	166	na	144	na	131	na	125	121	117	na	4
France[d]	na	121	115	109	105	102	98	93	90	86	75	73	5	5
U.K.[e]	na	na	103	101	102	98	na	94	na	95	na	na	na	na
Italy	na	76	75	71	68	64	62	63	57	52	47	46	1	5

. . . but barely leads Japan in proportion in labor pool

Per 10,000 labor force	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	% annual change[a] 1979–89	% annual change[a] 1988–89
U.S.	na	75.6	75.2	74.9	73.8	71.8	69.2	66.4	63.6	61.9	60.0	57.7	1%	3%
Japan[b]	75.6	73.6	71.7	68.8	67.4	63.9	62.4	58.1	57.1	55.6	53.6	50.4	3	4
Germany[c]	na	59.3	na	56.4	na	49.7	na	45.7	na	44.0	43.2	42.5	na	3
France[d]	na	49.7	47.6	45.4	43.7	42.8	41.1	39.1	37.9	36.3	32.1	31.4	4	5
U.K.[e]	na	na	36.3	36.2	36.6	35.3	na	35.3	na	35.7	na	na	na	na
Italy	na	31.4	30.9	29.4	28.4	27.1	26.6	27.3	24.9	22.9	20.8	20.8	2	4

Note: Table represents all scientists and engineers engaged in R&D on a full-time equivalent basis. **a** Annual change for Japan calculated for 1989–90 and 1980–90. **b** R&D scientists and engineers employed primarily in natural sciences and engineering. **c** Data are for former West Germany. **d** Figures increased in 1981 in part because of reevaluation of university research efforts. **e** Data comprise government and industry sectors only. **na**=not available. **Source:** National Science Foundation

U.S. share of GDP spent on R&D drops further behind Japan and Germany when only nondefense R&D is considered



Note: GDP = gross domestic product. **a** Data are for former West Germany. **Source:** National Science Foundation

TOTAL AND NONDEFENSE R&D: Italy's and Japan's R&D spending growing fastest

$ Billions, constant 1987	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
TOTAL R&D													
U.S.	$129.5	$129.8	$128.8	$125.4	$123.3	$120.6	$111.1	$102.3	$95.5	$91.1	$87.3	0%	4%
Japan	59.2	54.5	50.3	46.9	43.9	43.5	39.6	37.1	34.5	32.0	29.3	9	7
Germany[a]	28.8	28.2	27.2	26.5	24.9	24.4	22.4	22.0	21.8	21.1	21.4	2	3
France	20.9	19.9	18.8	18.1	17.5	17.3	16.8	16.0	15.6	14.6	13.3	5	5
U.K.	na	18.0	17.4	16.9	16.8	15.9	na	15.0	na	15.4	na	na	na
Italy	11.1	10.0	9.5	9.0	8.3	8.1	7.1	6.6	6.2	6.0	5.1	11	7
Sweden	na	3.6	na	3.7	na	3.4	na	2.9	na	2.5	na	na	na
NONDEFENSE R&D													
U.S.	$ 94.1	$ 92.3	$ 90.2	$ 86.2	$ 85.2	$ 84.9	$ 78.9	$ 73.7	$69.2	$67.8	$66.5	2%	4%
Japan	58.8	54.1	49.9	46.6	43.6	43.2	39.3	36.9	34.3	31.9	29.1	9	7
Germany[a]	27.3	26.9	26.0	25.2	23.6	23.2	21.4	21.0	20.9	20.2	20.4	1	3
France	16.0	15.6	14.6	14.2	13.7	13.7	13.3	12.6	12.0	10.9	10.3	3	5
U.K.	na	14.7	14.1	13.3	13.0	11.8	na	11.1	na	11.4	na	na	na
Italy	10.7	9.4	8.9	8.6	7.9	7.6	6.7	6.4	6.1	5.8	5.1	14	8
Sweden	na	3.2	na	3.3	na	3.0	na	2.6	na	2.3	na	na	na

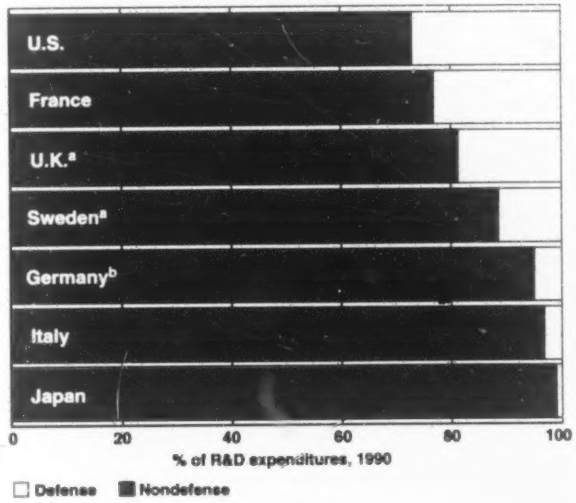
Note: Foreign currency conversions to U.S. dollars are calculated based on Organization for Economic Cooperation & Development purchasing power parity exchange rates. **a** Data are for former West Germany. **na** = not available. **Source:** National Science Foundation

ORIGIN OF CHEMICAL LITERATURE: U.S. dominates, increasing its share to nearly 30%

% of total[a]	1991	1987	1983	1979	1975
U.S.	29.2%	27.8%	27.0%	27.5%	25.8%
Japan	12.5	11.7	10.6	9.7	7.3
U.S.S.R.	11.1	12.7	17.0	19.0	24.6
Germany[b]	7.3	7.2	7.3	7.2	6.8
U.K.	5.7	5.7	5.8	5.9	6.3
France	4.2	4.2	4.1	4.2	4.1
China	4.0	3.3	2.1	0.3	0.1
Canada	3.0	3.0	2.7	2.9	2.7
India	2.7	3.0	3.0	3.1	2.7
Italy	2.4	2.3	2.5	2.2	2.1
Poland	1.5	1.7	1.8	2.2	2.1
Netherlands	1.5	1.4	1.4	1.3	1.1
Spain	1.4	1.4	0.9	0.7	0.5
Australia	1.2	1.3	1.3	1.2	1.1
Sweden	1.1	1.2	1.1	1.1	1.2
Switzerland	1.1	1.1	1.0	1.0	1.0
Czechoslovakia	0.8	1.2	1.1	1.4	1.6
All others	9.3	9.8	9.3	9.1	8.9
TOTAL PAPERS (THOUSANDS)	**453.6**	**386.5**	**371.4**	**370.8**	**317.5**

a Source of journal literature abstracted in *Chemical Abstracts* based on author's address. **b** Figures for years prior to 1991 are combined total for West Germany and East Germany. **Source:** Chemical Abstracts Service

U.S. and France each spend about a fourth of total R&D funding for defense



a Data are for 1989. **b** Data are for former West Germany.
Source: National Science Foundation

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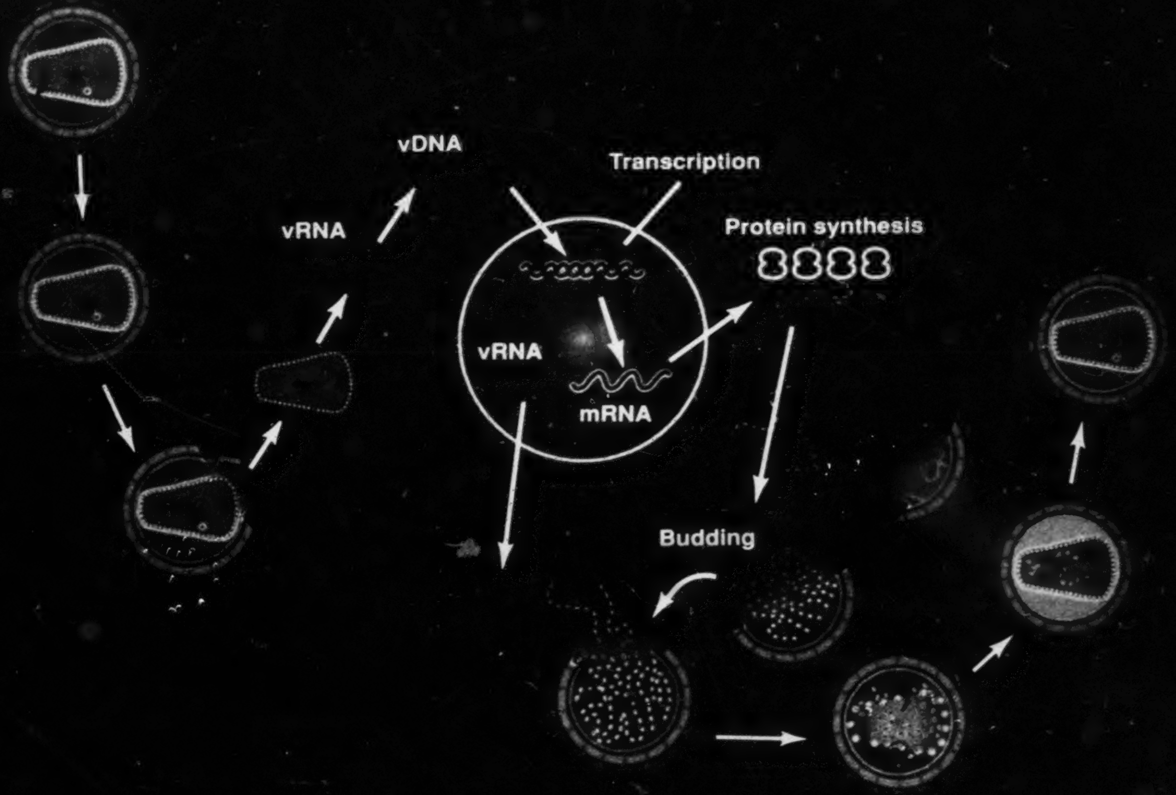
CHEMICAL & ENGINEERING NEWS
C&EN
AUGUST 24, 1992

IGURING INDUSTRIAL ACTIVITIES TO PREVENT GLOBAL CHANGE PAGE 7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Transcription
vRNA
Protein synthesis
vRNA
mRNA
Budding

AIDS RESEARCH

Slow progress reported at Amsterdam conference
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CHEMICAL & ENGINEERING NEWS

C&EN

AUGUST 24, 1992

NEWS OF THE WEEK

- U.S. lacks commitment to the field of bioprocess engineering, and needs to supply it with more research support and trained personnel, according to a report by a National Research Council panel **Page 4**
- National Science Foundation selects Rand Corp. to run new Washington, D.C.-based Critical Technologies Institute, which will help formulate technology policy **Page 5**
- Pfizer plans to spin off its specialty minerals group as a new company, Mineral Technologies, in which the public will be allowed to buy up to 70% of the shares **Page 6**
- Special commission to be formed to probe how NSF can expand its mission and play a major role in fostering links between research and industrial applications **Page 6**

COVER: Depiction of HIV-1 life cycle. Illustration courtesy of Upjohn

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NEWS FOCUS

Ways for industry and agriculture worldwide to avert damage to the environment were proposed at recent international industry-environment meeting. **Page 7**

BUSINESS

University licensing of technology to industry has grown markedly over the past decade, leading to some successful products—but not to big profits for schools that invest. **Page 17**

GOVERNMENT

Environmental issues likely will play a prominent role in discussions of North American Free Trade Agreement as it makes its way to Congress. **Page 22**

SCIENCE POLICY

Japan assesses changes in global industrial technology as well as its role in international technology and "technology fusion." **Page 23**

SCIENCE/TECHNOLOGY

New class of compounds, 2-phenylindole-3-acetamides, prove to have a unique mechanism of action in brain that causes anxiety-reduction and memory improvement. **Page 32**

NASA begins investigation into failure of tethered satellite system during *Atlantis* mission. **Page 32**

AWARDS

Winners of 1993 American Chemical Society national awards have been announced. **Page 34**

COVER STORY

Understanding of and therapy development for AIDS likely to be slow as researchers begin to discover just how tenacious the disease is. Page 26

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

UV alternative to chlorine

The report (C&EN, July 13, page 7) on the cancer risk associated with chlorinated drinking water from surface water sources cited Robert D. Morris' comments on the need for more effort to study the alternatives to chlorination. I suggest that we currently have sufficient knowledge to design drinking water treatment systems capable of delivering water that is safe from both pathogens and chemical by-products. Use of ultraviolet (UV) light is a physical disinfection method that is a better viricide than chlorine, inactivates microbes within seconds, requires no large retention tanks, is safe for operators and the community, introduces no residuals into the environment, and leaves no undesirable by-products at the disinfection doses used.

Ironically, North America has taken a leadership role in using UV systems of the type pioneered by Trojan Technologies Inc. for disinfecting wastewater (a greater technical challenge than drinking water disinfection); however, the Europeans have been quicker to recognize the advantages of UV for their municipal drinking water systems and are just now embracing UV for wastewater disinfection. Surface water treatment processes that use UV effectively have been developed, and many large European communities are even free of chemical residuals in their thousands of kilometers of distribution lines.

Even without making major changes in North American surface water treatment processes, UV disinfection of filtered surface water followed by chloramination for a residual would be a preferred strategy over chlorination for by-product control. Chloramination would also be more effective on distribution line biofilms than chlorination.

Several water- and wastewater-oriented national organizations in the U.S. are directly or indirectly supporting research on UV disinfection. Continuing research is always important, but what may be needed even more before we see widespread adoption of disinfection alternatives is the same as is needed in all areas of technology evolution: professional leadership by scientists, engineers, consultants, and policymakers in searching out and assimilating the best ideas to resolve our current problems, and then having done that, leadership by these professionals in breaking with tradition to bring these ideas to bear on the problems. The best available technology is not always the long-standing traditional technology against which new technologies are compared.

William L. Cairns
Research Manager
Trojan Technologies Inc.
London, Ontario, Canada

Arrogance in New Jersey

How can business leaders be so out of touch with political realities? I was amazed as I read your report on the Chemical Industry Council of New Jersey (C&EN, July 20, page 6). The lead item in their plan to improve the "hostile" climate for New Jersey chemical firms is to defeat the state's proposed form of initiative and referendum.

I am sympathetic to the industry's concern over the state's aggressive prosecution of environmental laws and regulations. I am sympathetic with their concern over the cumbersome provisions of the right-to-know legislation. Many of their proposals make sense. What I am not sympathetic with is their arrogance for the opinions of the people of New Jersey.

The chemical industry is in this mess because the people believe that the industry has abused the air, soil, water, and health of the people of New Jersey. Despite all of the jobs lost in the industry in New Jersey, chemists seem to be able to find jobs in the rapidly expanding pharmaceutical and biotechnology industries in the state.

Corrections

- Aug. 10, page 6: The Conference Board reported that the growth rate for gross domestic product slowed down to 1.4% in the second quarter, not that GDP fell 1.4%.
- Aug. 17, page 77: The speaker's name for the September ACS Lehigh Valley Section meeting should have been listed as Thomas J. Bzik, Air Products & Chemicals Inc. For more information on this meeting, to be held Sept. 18 at Lafayette College, Easton, Pa., call Charles Nutaitis, (215) 250-5218.

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University Technology Moves to Market via Patenting, Licensing

■ ***Licensing deals with industry have climbed and have led to new products, but schools aren't getting rich***

Ann M. Thayer,
C&EN Northeast News Bureau

Industry's interest in academic research is on the rise, as is universities' desire to see commercial development of their research inventions. In addition to collaborative R&D, academia and industry have been joining forces through licensing of university technologies, much of it chemically related. However, a few major products and lucrative licensing agreements may have raised university expectations, leading some industrial observers to suggest that universities have become more covetous in wanting to make money and more shrewd in trying to do so (C&EN, Feb. 3, page 9).

Despite concerns to the contrary, however, universities don't seem to be getting rich from such licensing deals, nor have business interests superseded universities' mission of research and education.

A striking example of the connection between universities and industry is biotechnology companies. Rarely can one be found without its core technology based on a licensed university discovery, its founders being university researchers, its scientific advisory board packed with faculty members, or a portion of its research conducted under contract in university laboratories. The increasing number and strength of scientific and financial associations between business and academia continues to raise serious conflict-of-interest issues.

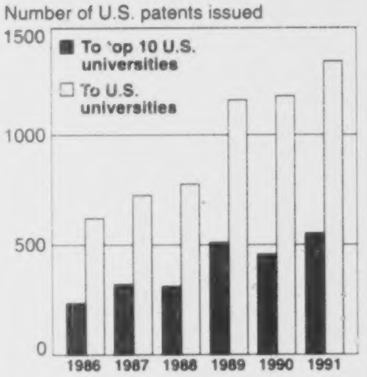
Many universities with technology to license have hired technology managers, who must balance academic, business, legal, and ethical issues. Discussions with some of these managers confirm that because of heightened concern, university-business relationships are being watched and managed more carefully, and strict guidelines are being put into effect. They further affirm that, concerning the mission of universities, education and publishing still take priority over industrial-related research and patenting. In terms of monetary returns from licensing, probably less than 1% is recouped on the billions spent on research. In fact, most technology managers interviewed say there is still a need to increase the awareness on campuses of the commercial potential of, and protecting of, university-based inventions and technologies.

Despite this lack of awareness, data that measure university patenting and licensing activities indicate tremendous growth during the past decade. Since 1986, the number of patents awarded to U.S. universities has more than doubled, reaching 1346 in 1991, according to data compiled for the Association of University Technology Managers (AUTM). Patents are a good measure of the marketability of university technologies, since a school is unlikely to incur the expense of patenting an invention unless there is a licensee lined up. And, licensees are reluctant to take the risk of developing an embryonic university technology unless there is some promise of exclusivity.

"If you don't have a licensee, patent filing is money at risk and it mounts up very, very quickly," says Lita Nelsen, associate director of the Technology Licensing Office at Massachusetts Institute of Technology. Filing costs alone are about $10,000 per patent, she says. MIT has about $2 million per year at risk in patent costs for technologies that are not yet licensed. "That's a factor of 10 to 50 times more than most schools can afford to do," she says. "MIT won't get its money back on every one, but has the licensing experience to know that statistically it is making the right judgments."

Not all schools have the expertise or income flow to allow them to do this. MIT, Stanford, and the University of California system each may set up several dozen licensing agreements in a year, accounting for nearly half of all university licenses and income. MIT has one of the most experienced and most active licensing offices, having been set up 60 years ago. License fees average $10,000 to $50,000 per year, whereas royalties may be a few to several percent of sales.

Patents to universities doubled in past six years



Source: Ronald T. Coslick Jr., University of Buffalo, for Association of University Technology Managers

In fiscal 1991 ending June 30, MIT had licensing and royalty income amounting to $4.4 million and is projecting about $5.5 million for 1993, which is enough income to cover expenses, says Nelsen. Fiscal 1992 was an anomaly, she adds, because the licensing office brought in more than $15 million, about $9 million of which came from a one-time gain. "A number of startup companies in which MIT had tiny bits of equity took advantage of the initial public offering window last October, and ... in many cases MIT sold [its interest]."

It is not MIT's policy to invest its money in new companies, although the university may take an equity interest partially in lieu of licensing or royalty income and has done so for about 15 companies. Like most schools, it generally keeps such interests at a very low level, under a few percent. MIT's equity interests also are very "passive," explains Nelsen, meaning that the university does not get involved in the operations of the company or take a seat on its board of directors. Many universities also have restrictions on whether faculty members can be company officers.

About 35 to 40 companies, including ImmuLogic, Interneuron, and American Superconductor, are based on technologies licensed from MIT. The single most active area of licensing has been biotechnology, says Nelsen. But, unlike many other schools, biotechnology accounts for only about one third of licensing activity, rather than a significant majority. This results partly from MIT's not having a medical school or hospital affiliation. However, the university does actively license in the areas of materials, computers, semiconductors, lasers, and electronics.

"Biotechnology is the area in which university-industry relations are the strongest," says Katharine Ku, director of Stanford's 23-year-old Office of Technology Licensing. Many emerging biotechnology companies license early-stage technologies from universities and then add value, she explains, putting more research effort into developing technologies further. Quite often, these small companies then will try to license the technology or product to a major pharmaceutical company for marketing. Some examples of successful products licensed for marketing include human insulin, α-interferon, and hepatitis B vaccine.

"All the interests of the parties involved are really well served with this kind of staging," she says. "Most major pharmaceutical companies are more interested in a more developed product than that which comes out of a university, and universities don't have the resources or the interest in trying to put more development effort into their basic invention."

The primary goal of licensing university technology is not to make money, stresses Nelsen of MIT, but to get the technology developed, a sentiment echoed by other university technology managers. "If people are in this for the money, they are in the wrong ball game," she says. As president of AUTM, Nelsen says that the organization's growing membership, which is nearing a thousand, is indicative of the rise in technology licensing.

Most universities making significant amounts of money, year-to-year profits in the millions, are those that have licensed a single blockbuster patent—such as the patent on genetic engineering shared by Stanford University's Stanley N. Cohen and the University of California's Herbert W. Boyer, the University of Wisconsin's vitamin D patent, and Michigan State University's cisplatin patent. "Clearly you don't run a business on hitting the lottery," she says, but adds that having an active licensing effort is important to take advantage of the "once in a decade" inventions when they arise.

Some universities, such as MIT and the University of California system, are starting to build license portfolios that bring a more regular income to support licensing activities. There often is a significant lag time, as much as 10 to 15 years, between discovery and an invention becoming an income-generating product. Licensing income for the fiscal year ending June 30 1992 was $31.3 million, up 41% from a previous record year in 1991, for the UC system. A factor contributing to the dramatic increases in income from just a few million dollars 10 years earlier is royalties being generated from "older" inventions. However, no single invention among the hundreds UC has licensed accounts for a majority of its licensing income. Although this is considered healthy, it is atypical.

Another factor has been a restructuring of UC's licensing efforts to be more "marketing oriented toward industry and service oriented toward faculty," says Carl Wootten, director of the UC system's Office of Technology Transfer. Wootten's office has oversight over the nine UC campuses as well as three national laboratories managed by the university. The UC system has offices or liaisons at each of its nine campuses, although Berkeley, Los Angeles, and the federal laboratories are large enough to be responsible for their own licensing efforts. UC's nine campuses represent more than $1.3 billion in R&D spending, or more than 10% of research spending among the top 100 U.S. institutions. Its licensed inventions are in a wide range of areas, including biotechnology, drugs, electronics, sensors, and superconductors.

Stanford University's biggest money earner is the 1980 Cohen & Boyer patent that is licensed to 180 companies, including most major biotechnology and pharmaceutical companies. About 70% of its $25.6 million in licensing and royalties income in 1991 came from this patent, says Ku, which it shares with the UC system. Stanford gets both licensing fees and royalties on products made through genetic engineering, whereas Boyer went on to become a founder of Genentech. Although not interested in starting new companies, Stanford does consider taking equity as another possible form of compensation.

Although the sum from its technology licensing sounds like a huge number, says Ku, it occupies only a niche, and an uncertain one at that, in terms of university finances. "The university cannot rely on technology licensing for operating revenues," says Ku. "As an example, the Cohen & Boyer patent has a life of 17 years, and so in 1997 that income is just going to drop to zero."

Coincident with much of the early growth in biotechnology, it became possible under a 1980 federal law for universities to hold rights to inventions developed with government money. It is rare that a university invention does not involve

MIT leads in U.S. patents awarded to universities

	Number of U.S. patents issued in 1991	R&D spending in 1990^{a} ($ millions)
Massachusetts Inst. of Technology	105	$ 312
U of California	87	1344^{b}
U of Texas	83	405^{c}
Stanford U	57	306
U of Wisconsin	45	310
U of Florida	44	140
Cornell U	41	300
Iowa State U	38	116
California Inst. of Technology	36	106
U of Minnesota	31	292
State U of New York	26	191^{d}
Johns Hopkins U	26	669^{e}
U of Michigan	22	311

a Some figures include spending at associated federally funded centers. **b** Santa Cruz campus not included. **c** Austin, M. D. Anderson Cancer Center, and SW Medical Center-Dallas. **d** Buffalo and Stony Brook campuses. **e** Includes Applied Physics Laboratory with $416 million in R&D spending. **Sources:** Ronald T. Coslick Jr., University of Buffalo, for Association of University Technology Managers; National Science Foundation

Boston University's investment in Seragen raises questions

Universities may take equity interests in startup companies in return for granting them rights to university technologies. In most cases, the level of investment in a single company is kept low, or investments are spread among different companies to minimize risk. An exception to this practice that has generated a great deal of attention is Boston University's majority interest in Seragen, a biotech company headquartered in Hopkinton, Mass., that develops fusion toxins for treating cancer and autoimmune diseases.

In 1990, Boston University's holdings in Seragen made headlines when university president John R. Silber unsuccessfully ran for Massachusetts governor. The university's interest was used as an example of questionable fiscal management whereby a significant amount of university monies were invested in a company that, like any development-stage biotechnology company, has an uncertain future. From 1987 until the company's initial public offering of stock this April, Seragen's primary source of operating funds, amounting to about $1 million per month, was Boston University. Although its interest was diluted and its risk somewhat decreased with the public offering, the university still holds a sizable 69% stake.

Boston University founded the company as a joint venture with members of its scientific faculty in 1979. The company holds license to technology developed by John R. Murphy, affiliated now with Boston University and formerly with Harvard. As a founder of Seragen, Murphy currently serves as both a director and paid company consultant. Silber and others from Boston University serve on the company's board of directors.

Although the university can elect a majority of the company's directors and control its corporate actions, Boston University has not been obligated to guarantee or provide funding to the company since the stock offering. Occurring at a low point for biotechnology stocks, the offering raised only $36 million, and Seragen will have to seek funds from other sources because it has no product sales. Analysts who view the company's science positively believe the company can succeed in raising money.

The university's 69% interest is worth $72.5 million at current stock prices, a figure less than the university has invested in the company, and reportedly equivalent to about one third of Boston University's endowment. In addition, the value of its investment has decreased 27% from what it was at the time stock was offered to the public. Under an agreement with the company, the university is restricted in the number of shares it can sell for about one year after the initial stock offering.

As a charitable institution, Boston University's investments fall under review and monitoring by the state attorney general, who could force the university to sell all or part of its stock. However, doing so is tied up with complicated questions relating to conflicting interests of the company and university. For example, if it were considered to be in Boston University's best interest to cut its risk by decreasing its holding, doing so might harm the company by causing investors to lose confidence. And, if stock prices fell, this could have negative repercussions on any remaining university investment in Seragen.

Boston University has been an extraordinarily committed, long-term investor, says Richard C. Svrluga, president and chief executive officer of Seragen. The university has told the company that it does not intend to sell its stock in the near future. Therefore, the university must wait and see whether Seragen will be successful in bringing products to the market and whether the potentially sizable return on its investment will come from royalties to be paid on product sales.

government funding, says Joyce Brinton, director of technology and trademark licensing at Harvard University, since an average of about 60% of university research funding comes from government sources. Before the law, inventions were owned by the government and offered for nonexclusive licenses or not licensed at all, falling into the public domain.

One of the goals of the law, which some university technology managers believe has been borne out by experience, was to provide a mechanism that would promote the development of these technologies through a promise of exclusivity for companies and by providing an incentive for universities. Although the law has been hotly debated, its effect has been clear with the growth in number of university patents and in new products that have originated from university research. "For a lot of university inventions, one has to have a lot of imagination before one can see what the product is going to be," says Brinton. "But in the biotechnology area, that distance seems to be somewhat shorter."

Contributing to the incentive for licensing, says Brinton, is that "government research funding is becoming a little tighter and so the possibility of generating some additional money from research to support research becomes increasingly important." However, technology managers do not expect that licensing income will replace, or even approach, that from other sources of support.

Because sufficient funds are not available to the licensing office, Harvard does not have a policy of investing in companies, "Harvard is talking about ... whether the university should feel free or not to take equity in situations where it feels that it is appropriate and there will not be undo conflict," says Brinton. "At the moment our practice in general, although it is not a stated policy, is that we don't take equity in companies."

However, a few years ago its medical school took $30 million seed capital and set up a venture capital investment group called Medical Science Partners. Medical Science Partners itself has established about 10 companies, says Brinton. Along with its medical school, Harvard has been the source of many licensed technologies and faculty members who have founded startup biotechnology companies, among them Genetics Institute and Biogen.

Revenue from its licensing program is about $4.5 million on research spending of $285 million. The best way to establish the value of a university discovery is through a negotiation process, she explains. "We have to test the marketplace to see what it is actually worth, as in the end we can only get what somebody is willing to pay."

Opinions vary greatly as to the value that should be assessed to university technologies. "There is a lack of realism on both [university and industry] sides," adds Nelsen of MIT. "There are very, very strong opinions on whether universities are realistic in asking to be recognized as unique resources or whether they are getting greedy and unrealistic. [MIT's] view is to recognize that the technology is very embryonic and is going to require a lot of development." Thus, the university tries to work out arrangements with companies that will share both the risk and the rewards. Large companies tend not to be so interested as small companies in licensing embryonic technologies.

"In some instances, universities dealing with their own intellectual property sell it too cheaply," says Gary Munsinger, president of Research Corporation Technologies (RCT), a Tucson-based technology licensing firm. "And sometimes, on the other hand, they may be unrealistic in their expectations of what they should receive." RCT is in the business of evaluating, patenting, and licensing university technologies and provides services to many smaller universities that don't have the money, expertise, or breadth of research to support a licensing office. In 1991, it worked with 113 participating institutions.

Munsinger believes that a university must have R&D spending of $250 million to $300 million per year to warrant a full-service licensing program. "To have the critical mass of expertise to cover [licensing]," says Munsinger, "you've got to have a fairly sizable operation at a university and you have [to have] great scope and depth of research to justify economically the staff that would be required to do what we do."

Universities always have more opportunities for employment of their resources than they have resources, and technology licensing may require taking discretionary funds from other activities. "It comes down to the question of how well [a university] can do this technology transfer business if there are other demands on its resources," Munsinger adds. "Can it really afford to create a critical mass of talent dedicated solely and exclusively to that function?"

Because it is profitable, RCT has its own money to invest in developing technologies prior to licensing or in starting up companies or joint ventures, unlike most universities. In 1991, RCT brought in $43.3 million in revenues from licenses and royalties, an increase of about 34% from the previous year. Of that, $28.2 million, or 65%, was distributed to institutions and inventors. After expenses, RCT had a net profit of $1.19 million, down 68% from the previous year because of higher than anticipated litigation costs related to patents.

RCT uses a market approach and tries to rapidly assess the potential value of university intellectual property on a case-by-case basis, as it had for the fullerenes. In 1991, 635 new disclosures were screened, with 221 of those in life sciences and 407 in physical sciences. If an invention has commercial potential, RCT will apply for patents—including patents in foreign countries, which many universities won't do because of the added expense—and will develop a commercialization plan with which to approach the best companies for licensing. ☐

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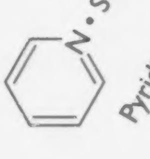
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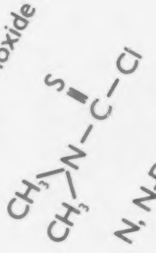
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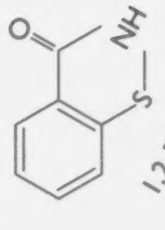
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CHEMICAL & ENGINEERING NEWS
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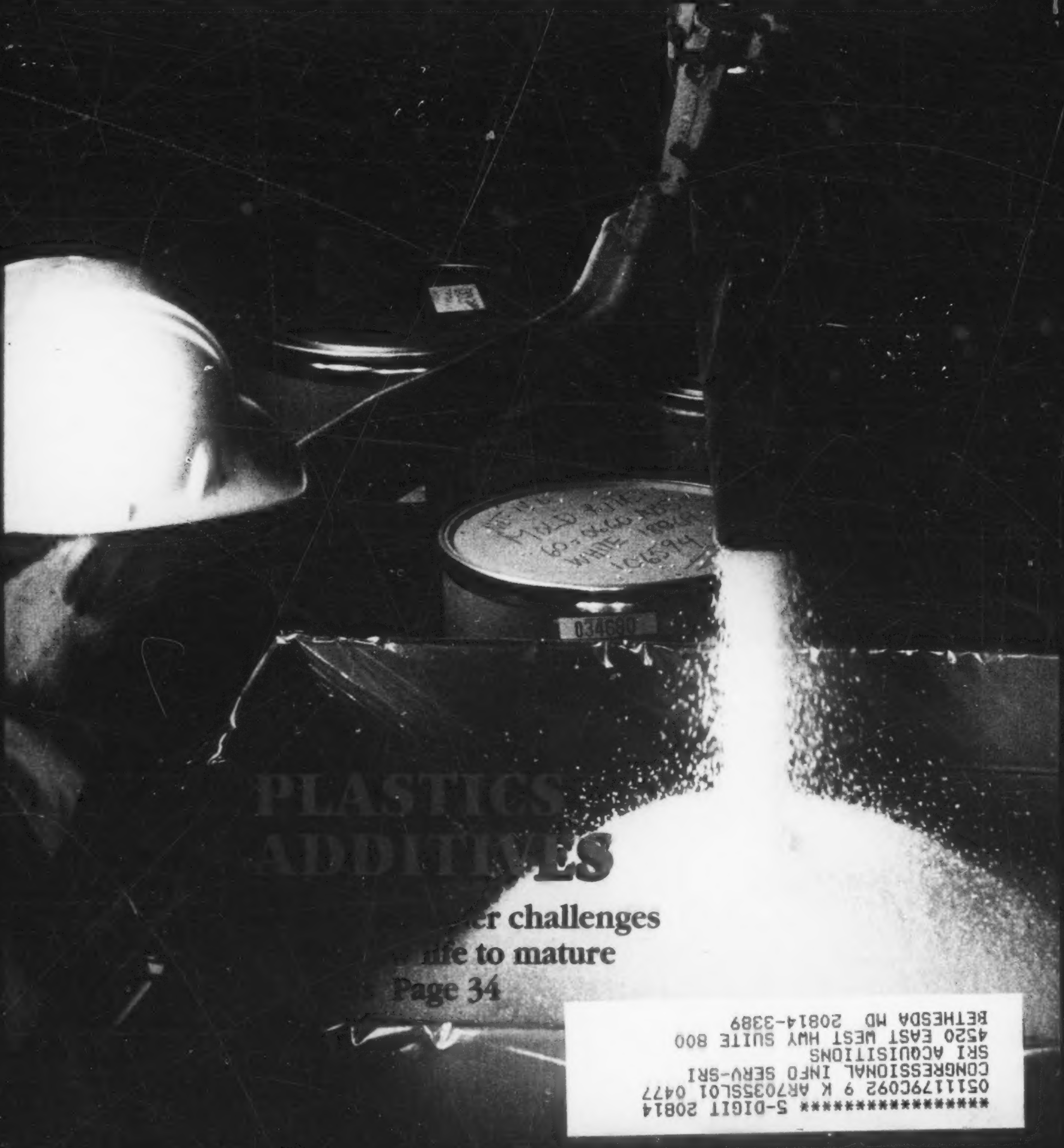
PEPTIDE AND DNA ANALOGS SYNTHESIZED AND CHARACTERIZED PAGE 27



PLASTICS ADDITIVES

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CHEMICAL & ENGINEERING NEWS

C&EN

AUGUST 31, 1992

NEWS OF THE WEEK

- Dutch scientists prepare organic polymers that are more metal-like in electrical properties than any previously known. Page 8
- Mycogen has settled dispute with Novo Nordisk over patent rights on biopesticide. Page 9
- Special poster session at ACS national meeting in Washington spotlighted Russian materials science research. Page 9
- Hurricane Andrew generally left chemical plants unscathed as it roared through Louisiana last week. Page 9
- ACS decided during the national meeting to expand activities in such areas as public outreach, education, and professional development. Page 10
- Researchers at Searle and Du Pont have developed a new class of drugs that attack inflammatory diseases. Page 11
- In-situ method for preparing thin films of thallium superconductors has been found by Du Pont scientists. Page 11
- Dollar's dive to record lows against the German mark promises to boost U.S. chemical exports to Europe. Page 12

COVER: Worker fills container with final compounded polymer. Photo courtesy of Ciba-Geigy

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CENEAR 70 (35) 1-80
ISSN 0009-2347

BUSINESS

Revenues were up for biotech companies in the first half, but only five firms had profits, largely because of increased expenses from mergers, R&D, and marketing. **Page 15**

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The Senate tacked on new tax provisions to the energy policy bill, substantially boosting its chances for enactment before the end of the 102nd Congress. **Page 24**

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Nanometer-scale galvanic cell, much smaller than a red blood cell, could provide a route to the study of electrochemical processes at the atomic level. **Page 29**

Three-dimensional molecular modeling software will be offered for Digital's Alpha computers under a joint marketing pact between Digital and Molecular Simulations. **Page 30**

EDUCATION

Planned cuts in San Diego State University faculty that would have hit the university's chemistry department hard have been put off at least until 1993. **Page 33**

PRODUCT REPORT

Forecast growth for plastics additives industry has producers gearing up to meet demands of a global market, needs of new polymer systems and end-use customers, and requirements of new and pending environmental rules. Page 34

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1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

Borane-methyl sulfide complex spill reported

We wish to report a recent incident involving a spill of borane-methyl sulfide complex that resulted in injuries to three employees, two serious enough to warrant hospitalization for medical observation.

The accident occurred as an 800-mL Sure-Seal bottle of neat borane-methyl sulfide complex (Aldrich catalog no. 179825) was unpacked for storage. The bottle had been removed from its protective packaging and was being carried to the refrigerator for storage when it burst spontaneously, splashing one person over much of his body with the reagent. With the assistance of another person, he was placed under a safety shower immediately, and contaminated clothing and shoes were removed. The water from the shower began to react with the spilled borane-methyl sulfide, worsening the already deteriorating laboratory atmosphere, and the laboratory was evacuated as soon as the employee could be moved. Both employees involved at the shower suffered from intense irritation to their eyes and respiratory passages, and were treated with oxygen and eye irrigation.

Our investigation of this accident suggested that it was probably the result of a potentially defective glass container of borane-methyl sulfide. The bottle had been inspected immediately prior to the accident and was not warm to the touch, nor did it or the packaging show any signs of damage. However, shards of the broken bottle recovered after the accident revealed that the bottle appeared to have fractured from within at a particularly thin point (1.5 mm thick) in the side wall of the bottle. We believe that the breakage was probably caused by an accumulation of hydrogen within the bottle.

Upon subsequent discussion of this incident with Aldrich, we learned that all borane complexes, with the possible exception of borane-amine complexes, decompose in a time- and temperature-dependent manner to higher borone hydrides and hydrogen. Thus, any borane

Research fraud

The federal prosecutors' decision not to press criminal charges against Thereza Imanishi-Kari, as reported in Pamela Zurer's article (C&EN, July 20, page 5), is probably a wise one. Unless research fraud is of a kind easily discernible, as for example plagiarism or fabrication of research data based on fictitious experiments, it is difficult, if not impossible, to prove that fraud has occurred, whether or not the jury selected in a criminal trial is composed of knowledgeable scientists. Nonrepeatability of experimental results is, by itself, not proof of research fraud, since other explanations are possible without impugning the integrity of the authors.

On the other hand, even if this highly visible case had been prosecuted, whether successfully or unsuccessfully, the fact remains that one may commit research fraud without its being detected, thereby increasing one's productivity, and, in this way, advancing one's career. It is also true that Margot O'Toole's career was very nearly destroyed as a result of her questioning the authenticity of research data in the famous 1986 *Cell* paper [**45**, 247 (1986)]. Is the withdrawal of the retraction of that paper by its senior author, Nobel Laureate David Baltimore, a reaffirmation of his initial evaluation of O'Toole as a "disgruntled" junior scientist? Further, it would appear that this long-drawn-out case has come full circle, which leads to the question: What does the Dingell committee do next?

What it has done is to partly expose academia's dark side and the ineptness of the National Institutes of Health in bringing its lengthy fraud investigation to a successful conclusion. Possibly the most important contribution this committee

Correction

- Aug. 24, page 28: The crystal structure of HIV-1 reverse transcriptase, not the HIV-1 Tat protein, has been solved to 3.5-A resolution; see *Science*, **256**, 1783 (1992).

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Biotech Firms' Revenues Up But Earnings Weak in First Half

■ ***Higher expenses from mergers, acquisitions, R&D, and marketing take big bite out of revenues, drive down earnings***

Biotechnology companies had very mixed results in the first half of 1992. Although revenues increased significantly for many companies, relative to the same period last year, earnings continued to be bleak. This situation may change in the second half of the year as some companies finally rid themselves of merger- and acquisition-related expenses. But at the same time, increasing R&D spending and costs associated with setting up marketing and sales efforts will continue to eat away at revenues.

The big exception is Amgen, which has clearly established itself as a biopharmaceutical force with two major products—the blood cell stimulants erythropoietin (EPO) and granulocyte colony-stimulating factor. Amgen's revenues grew 64% over first-half 1991 to $481 million. Although Amgen's 1991 annual sales already placed it among the Fortune 500, the question for 1992 will be whether it breaks the $1 billion mark.

First-half 1992 earnings of $135 million following a loss of $11.5 million in last year's first half resulted in a profit margin of 28% for Amgen, allowing it to increase R&D spending 41% to about $81 million. If not for a special charge taken in the first half of 1991, earnings would have increased 75%. The special charge, for $129 million and related to an arbitration settlement with EPO licensee Johnson & Johnson, contributed to Amgen's first-half 1991 loss.

The sizable increases in revenues registered by many other companies can be deceptive since they measure gains from very small revenue bases or those resulting primarily from R&D contract revenues or interest income rather than from product sales. Revenues of companies with sales or royalties from major products, such as Biogen, Centocor, Chiron, Genentech, Genzyme, and Immunex, increased an average of 60%. However, excluding Genentech and Amgen, they increased 82%.

Genentech's revenues rose only 1%, as product sales dropped 4% in the first half compared with the year-earlier period. Much of this was due to a 12% drop in sales of its antithrombolytic, tissue plasminogen activator, in the second quarter, but was counterbalanced by an 8% rise in human growth hormone sales. With R&D expenses up 37%, Genentech's earnings for the first half dropped 77% to $6.9 million.

Similarly, Immunex's sales were hurt by its now resolved marketing problems with Behringwerke and Hoechst

Only five biotech firms had profits in first-half 1992

$ Thousands	Revenues[a]	Earnings	% change from first-half 1991 Revenues	% change from first-half 1991 Earnings	Profit margin[b] 1992[c]	Profit margin[b] 1991[c]
Affymax	$ 6,004	$ –4,633	561%	nm	def	def
Agouron Pharmaceuticals	4,274	–4,545	82	nm	def	def
Alkermes	3,350	–4,085	2580	nm	def	def
Amgen	481,459	134,888	64	nm	28.0%	def
Biogen	40,027	1,479	43	–71%	3.7	18.4%
BioTechnology General	3,148	–4,772	45	nm	def	def
Cambridge Biotech	20,771	1,410	63	nm	6.8	def
Centocor	42,188	–85,490	72	nm	def	def
Cephalon	4,000	–2,388	–21	nm	def	30.8
Chiron	125,503	–45,086	96	nm	def	15.1
Cor Therapeutics	881	–4,285	–47	nm	def	def
Cytogen	8,715	–5,466	290	nm	def	def
Genentech	264,964	6,936	1	–77	2.6	11.8
Genetic Therapy	832	–3,389	576	nm	def	def
Genetics Institute	33,858	–37,461	29	nm	def	def
Genzyme	94,695	–48,709	116	nm	def	15.9
Gilead Sciences	1,140	–1,758	128	nm	def	def
Icos	1,328	–3,127	225	nm	def	def
Immune Response	5,499	–754	57	nm	def	def
Immunex	31,764	–6,241	29	nm	def	def
Isis Pharmaceuticals	4,796	–9,269	37	nm	def	def
Liposome	5,390	–3,083	45	nm	def	def
MedImmune	7,914	266	327	–82	3.4	18.9
Oncogene Science	5,974	–2,246	51	nm	def	def
Regeneron	6,726	–6,976	27	nm	def	def
Ribi ImmunoChem	1,009	–1,759	61	nm	def	def
Scios	4,460	–5,964	–2	nm	def	def
Synergen	23,494	–3,404	182	nm	def	def
SyStemix	207	–15,889	–79	nm	def	def
Xoma	3,810	–19,202	–62	nm	def	def

a Includes product sales, contract research, royalty, and interest revenues for calendar year. **b** After-tax income as percentage of revenues. **c** First half. **def** = deficit. **nm** = not meaningful.

Organic Intermediates

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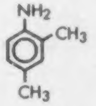
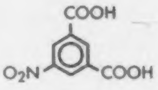
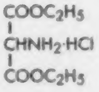
2,4-Xylidine
and other isomers



5-Nitroisophthalic acid
and derivatives

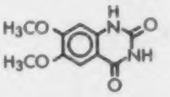


Aminomalonic acid diethyl ester · HCl
and Acetylaminomalonic acid diethyl ester

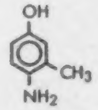


$$\begin{array}{c}COOC_2H_5\\ |\\ CHNH_2{\cdot}HCl\\ |\\ COOC_2H_5\end{array}$$

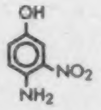
6,7-Dimethoxy-quinazoline-2,4-dione



4-Amino-m-cresol
and other isomers



4-Amino-3-nitrophenol



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Agricultural biotech firms not yet breaking even

Companies developing genetically engineered plants, pesticides, and foods have yet to turn the corner financially. A few are getting close—such as Mycogen, Ecogen, and Calgene—but have been spending money to acquire businesses and products, and to prepare for marketing. Expenses also have remained high because it has taken several years for companies to develop the science behind new products. Revenues are up, however, for five of the six most prominent agricultural biotechnology firms and losses remain modest in comparison to high-spending biopharmaceutical companies.

$ Thousands	Revenues[a]	Earnings	% change from first-half 1991		Profit margin[b]	
			Revenues	Earnings	1992[c]	1991[c]
Biosys	$ 1,854	$–2287	198%	nm	def	def
Calgene[d]	10,209	–2387	–19	nm	def	2.2%
Crop Genetics	1,407	–2949	37	nm	def	def
DNA Plant Technology	5,379	–7800	3	nm	def	def
Ecogen	3,847	–5788	11	nm	def	def
Mycogen	19,752	–1439	175	nm	def	def

a Includes product sales, contract research, royalty, and interest revenues for calendar year. **b** After-tax income as percentage of revenues. **c** First half. **d** Only first quarter available. **def** = deficit. **nm** = not meaningful.

Roussel, licensees for granulocyte macrophage-colony stimulating factor (C&EN, July 27, page 21). Sales still rose 74% to $22 million for the first half of 1992. Increased R&D spending, as the company expanded its clinical trials, led to a net loss of $6.2 million.

Other than Amgen and Genentech, only three of the 30 biotech firms surveyed—Biogen, Cambridge Biotech, and Medimmune—showed a profit for the first half of 1992. Biogen's revenues grew substantially, primarily because of royalties on major biopharmaceuticals such as α-interferon and hepatitis B vaccine. But in putting its first proprietary drug product, the antithrombolytic Hirulog, into advanced clinical trials, R&D spending rose 37% to $28.3 million and earnings dropped 71% to $1.5 million.

Genzyme and Chiron, which recorded profits in the first half of 1991, reported losses for the same period in 1992. First-half revenues for Genzyme increased 116% to $94.7 million, largely owing to sales of Ceredase, its product for treating Gaucher's disease. But nonrecurring charges of $51 million for acquiring in-process R&D and $17 million to write off its option on Neozyme II led to a net loss of $48.7 million.

Chiron was in a similar situation with a $40 million charge related to its acquisition with Ciba-Geigy of the Italian vaccine producer, Sclavo. This contributed to a net loss of $45 million, despite revenues up 96% to $126 million for the first half. R&D spending doubled to $60 million, in part because of $17 million for research acquired with Cetus in December 1991. Cetus' oncology business, which now includes the May 1992 U.S. launch of interleukin-2, contributed $18.8 million in sales.

Along with Genzyme and Chiron, several other prominent companies—Centocor, Genetics Institute, SyStemix, and Xoma—reported huge losses. With revenues up 72% to $42.2 million for the first half, Centocor cut its loss to $85.5 million after reporting a $117 million loss for the year-earlier period. Centocor's antisepsis drug, Centoxin, did contribute $9.6 million in European sales in the first half of 1992. And Centocor's new alliance with major pharmaceutical partner Eli Lilly is expected to bring in at least $100 million.

As for Genetics Institute and SyStemix, both had special charges relating to mergers. Xoma's loss, however, was due primarily to a drop in collaborative R&D funding and a $3.3 million legal settlement. SyStemix took a $12.2 million special charge relating to Sandoz's acquisition of a 60% interest in early 1992. For the first half of 1992, SyStemix reported a net loss of $15.9 million. Similarly, Genetics Institute reported a $37.5 million loss after taking a $30 million charge associated with American Home Products' acquiring a 60% stake in January.

Ann Thayer

PLASTICS ADDITIVES

Susan J. Ainsworth, C&EN Houston

Plastics are everywhere—in automobile parts, in components for houses and buildings, and in packaging for everything from food to electronic parts. Plastics would not be able to perform such diverse functions without the assistance of a very broad range of plastics additives. Polyvinyl chloride (PVC), polyolefins, polystyrene, and polyester resins rely most heavily on additives. Without them, some plastics would degrade during processing and, over time, the polymers would lose impact strength, discolor, and become statically charged, to list just a few problems. Additives not only overcome these and other limitations but also can impart improved performance properties to the final product.

Because plastics and additives markets are so interdependent, their growth rates are virtually one and the same: The plastics business has been buffeted by recession, and the additives business has been hit just as hard. But things are looking up, companies say. The plastics additives industry should enjoy moderate growth during the next five years as plastics consumption recovers from the recession.

U.S. demand for plastics additives is projected to increase 4.1% per year to 12.5 billion lb in 1996, if manufacturers of these additives can lower resin costs and improve physical characteristics and processibility of plastics, according to the May 1992 study, "Plastics Additives in the 1990s," by Freedonia Group, a consulting firm based in Cleveland.

For the most part, additive producers agree. Many expect to see volume growth of between 2 and 6% during the next five years, depending on what additives are taken into account. For example, according to Avron Magram, vice president and general manager of the plastics additives and specialty lubricants group at Hüls America, "If you include a no-growth business such as commodity plasticizers, growth rates should fall to around 1.5 to 2%. If that business is not considered, my outlook is much more bullish and I put growth rates at 5 to 6% per year."

Although plastics and plastics additives businesses are fairly mature, the additives business is far from stagnant. On the contrary, additive producers are perhaps busier than ever trying to meet the changing needs of their customers.

For example, their most prized customers—the resin producers—are becoming more multinational. In response, many U.S.-based additive suppliers are globalizing their distribution networks, setting up more manufacturing and technical centers outside the U.S., and reshuffling internal divisions to strengthen the geographic scope of their businesses.

Additives producers are also hard at work tackling a number of their customers' technical challenges, hoping to carve out new niches and more profits. New additive technologies are needed to address the problems that accompany new polymer systems and to meet increasing performance demands from end-use customers, such as the automotive industry.

Another challenge facing producers: developing alternative additives to meet customer requirements that are changing as a result of proposed legislation or public demands for environmentally friendly and recyclable plastic products. "We believe that environmental issues provide opportunities for us to develop new technology and to differentiate ourselves from competitors," says Jean Schaeflé, president of Ciba-Geigy's U.S. pigments division. "We have to consistently produce high-quality pigments that provide our customers and [our customers'] customers with the qualities they want, but our pigments also have to be environmentally acceptable. [They have to be] acceptable in the workplace and in production processes, acceptable from a waste- and resource-management standpoint, and acceptable for consumers."

Although regulations present opportunities for additive producers who can develop alternative product technologies, regulations also have negative effects on businesses—compliance is usually labor intensive and adds costs for which there is no return on investment. Those companies that do not have the capital or the clout to face these challenges will be added to the ever growing list of casualties in the continually consolidating additives business, says Steven Hopper, marketing manager for PVC and target markets at C. P. Hall, based in Chicago.

Additive suppliers say they have to provide more research and development support to the plastics industry. Formulating with plastics additives has always been a tricky business. Incorpo-

Ciba-Geigy photo

Worker scoops out granular pigments that will be used in the production of polymers

rating additives in a polymer requires a fine balance between the properties of the polymer and the additive. Formulating a plastic for enhanced ultraviolet light resistance, for example, can have an impact on the polymer's color stability and retention of its functional characteristics. Similarly, incorporating antioxidants in a polymer melt can inhibit the cross-linking ability of a peroxide catalyst. So formulators need to choose carefully additives that not only possess a specific functionality but that also minimize the effect on other additives and the formulated plastic. Consequently, both the additive supplier and the resin formulator, compounder, or manufacturer have had to devote considerable research and development time to achieve the best balance of properties in the final product. But now, additive suppliers say they are experiencing a greater proportion of the pressure.

With the U.S. plastics business recovering from the effects of the recession, few resin manufacturers want to spend the capital required to fully research new additive offerings. In many cases, it's easier and less costly for them to keep using what works now. So additive producers that want to sell their products must do the testing required and provide proof statements that show their product has better cost or performance benefits than resin manufacturers' old standbys.

"Additive producers must bring more technology to the table to win business," says Hopper. "Proof statements have become very sophisticated." The statements must be broader and show—in detail—what parameters the additives have been tested for and how they compare with other products on the market. "There's more pressure on the additive suppliers to provide vast amounts of data on their additives," adds Hopper. "Simply saying your product is new and improved does not get you in the door anymore."

At the same time, additive producers face a major technical challenge of providing quality and consistency—a concept that has permeated the industry. "Even if a UV absorber makes up only one tenth of one percent of a plastic formation, that additive must be exactly the same day after day. We have to set a standard and meet it each and every time. That's a big technical challenge considering that one additive may have a positive effect on a polymer as well as an offsetting negative effect at the same time," says Hüls' Magram.

Recognizing the business potential behind new additives technology, several additive producers are aggressively involved in developing compatibilizing agents for blends or alloys. "It's a small area now, but one in which we see innovative growth opportunities," says Robert Terranova, vice president of inorganic chemicals at Lonza. Thomas E. Galvanek, a vice president at the Houston-based international plastics and chemicals consulting firm Phillip Townsend Associates, agrees that the market for compatibilizing agents is one of the most dynamic and rapidly growing specialty chemical areas. On the basis of data in the firm's recently published report on this topic, overall sales of these products are projected to increase from $20 million in 1990 to more than $100 million in 1995.

Compatibilizing agents provide permanent miscibility or compatibility between otherwise immiscible or partially immiscible polymers, creating homogenous materials that do not separate into their component parts. Because the desired compatibilization can be achieved in many ways, a wide array of materials can function as compatibilizers. Several of the most prevalent types include maleic anhydride modified polymers, monomeric polymers, and silanes.

Compatibilizing agents have been used in polymer blending and alloying for the past decade. However, recently these materials have developed into a significant segment of the plastics additives industry. Compatibilizers are primarily used in the production of polymer blends and alloys produced from virgin resins. Polycarbonate is by far the most important base resin, accounting for about three quarters of all compatibilizer demand in 1990, says Phillip Townsend Associates. The only other significant base resin is nylon. The greatest area of potential for compatibilizers is in recycling of plastics. By 1995, says the consulting firm, recycling will account for more than half of the demand for compatibilizers.

Additive producers are also hard at work trying to improve products they already supply to end-use customers. For example, William Avrin, vice president and general manager of the polymer additives department at American Cyanamid, believes growth opportunities for plastics additives used in the automotive industry will spur producers to improve the performance and longevity of plastics used to make parts. "Automotive companies are now trying to build cars that last 10 years, so

How do additives work?

Plastics additives include an array of products that can improve the performance of plastics or overcome processing problems. The functional properties of some of the major classes of plastics additives are discussed below. But the plastics industry also relies on several other classes of additives such as antiblocking and antislip agents, biocides, peroxide and polyurethane catalysts, colorants, coupling agents, defoamers, fillers and reinforcements, plasticizers, thickeners, and wetting agents.

Antioxidants retard the oxidative degradation of a plastic. Degradation is initiated when free radicals—highly reactive species with an unpaired electron—are created in the polymer by heat, ultraviolet radiation, mechanical shear, or metallic impurities. Without the protection of antioxidants, loss of molecular weight, brittleness, discoloration, cross-linking, and deterioration of other polymer properties would occur.

When a free radical is formed, a chain reaction begins that initiates polymeric oxidation. Subsequent reaction of the radical with an oxygen molecule yields a peroxy radical, which then reacts with an available hydrogen atom to form an unstable hydroperoxide and another free radical. In the absence of an antioxidant, these reactions become self-propagating and lead to polymer degradation.

There are two basic types of antioxidants—primary and secondary. Primary antioxidants intercept and stabilize free radicals by donating active hydrogen atoms. Hindered phenols and aromatic amines represent the two main types of primary antioxidants. Secondary antioxidants prevent formation of additional free radicals by decomposing the unstable hydroperoxides into a stable product. Phosphites and thioesters are secondary antioxidants that function by decomposing hydroperoxides, thus preventing free-radical formation. Phosphites are also frequently used as costabilizers with polyvinyl chloride (PVC) heat stabilizers. Secondary antioxidants, or synergists, are often used along with primary antioxidants. They decrease the discoloration of the polymer, and may also regenerate the primary antioxidant.

Antistatic agents or antistats, when formulated in or coated on plastics, dissipate static electrical charges. Such charges build up on the surface of plastics because they are insulating materials and cannot independently dissipate a charge. Dissipating static electricity prevents problems such as sparking, dust attraction, or interference during processing.

There are two types of antistats—external and internal. External, or topical, antistats are applied to the surface of a polymer through techniques such as spraying, wiping, or dipping. These coatings often serve a cosmetic function by keeping dust from settling on plastic surfaces. Internal antistatic systems are compounded into the resin during processing. These agents have the ability to replenish the polymer's antistatic protection, often worn off during handling, through a process called blooming—the migration of the antistat to the polymer surface. The internal antistats, therefore, can offer long-term protection against static electrical charges.

Antistats are usually hygroscopic compounds, and thus absorb moisture from the surrounding air. It is this conductive layer of water on the polymer surface that disperses the charge. The two major types of specialty antistatic agents are quaternary ammonium compounds and amines, and their associated derivatives. Phosphate and fatty acid esters, polyhydric alcohol derivatives, sulfated waxes, ethoxylated and propoxylated aliphatics and aromatics, and other materials are also used.

Chemical blowing agents (CBAs) are used to make foamed plastics. Physical blowing agents are volatile liquids or compressed gases that, because of changes they undergo during processing of the plastic, give the plastic a cellular structure. Gases, such as nitrogen, carbon dioxide, and air, or low-boiling liquids, such as short-chain hydrocarbons, are dissolved in the resin and are volatilized by the release of pressure or the heat of processing. CBAs are solids that generate gases when decomposed by the heat of processing, generating a foamed product. Mainly solid hydrazine derivatives, CBAs are designed to decompose within well-defined temperature ranges that can be lowered by the addition of activating compounds. Some heat stabilizers, such as tribasic lead sulfate, dibasic lead phthalate, and dibasic lead phosphite, may act as activators that reduce the temperature needed to produce the gas.

Compatibilizers are agents that provide permanent miscibility or compatibility between otherwise immiscible or partially immiscible polymers, creating homogenous materials that do not separate into their component parts. Compatibilizers function as solid polymeric surfactants, in that they promote miscibility by reducing interfacial tension. They typically concentrate at the phase boundaries, and regulate interphase adhesion.

These compatibilizing agents can be further classified as reactive and nonreactive. Reactive compatibilizers chemically react with polymer systems during compounding, and they are effective across generally broader ranges of systems than are nonreactive types. However, the degree of compatibilization they provide depends strongly upon compounding conditions. Nonreactive compatibilizers, which are often block or graft copolymers (but may not be polymers at all), interact physically, not chemically, with the polymer system during compounding. Generally, nonreactive compatibilizers can only be used with a fairly narrow range of matrices.

Flame retardants are chemical compounds that can be physically blended into a resin, or can react to become part of the polymer. They are used to treat a product so that its resistance to burning is improved or modified. Flame retardants are designed to interfere with combustion both physically and chemically but not to prevent the product from burning if sufficient heat and oxygen are present. Such interference can occur in the vapor phase, in the condensed phase, or in both.

Heat stabilizers are added to resins to prevent thermal degradation. Although such protection is usually essential in processes such as molding and extrusion, particularly for PVC resins, these additives also extend the useful life of finished products that are exposed to heat. Lubricants, UV stabilizers, and synergistic antioxidants, especially organophosphites, are frequently used in conjunction with heat stabilizers. The most typically used chemicals include lead compounds, organotin compounds, and mixed metal-salt blends based on such products as barium, cadmium, and zinc.

Impact modifiers are formulated into plastics to improve the resistance of the finished product to stress. These additives are usually elastomeric, although certain types of plastics may also be used. Major classes of impact modifiers are methacrylate-butadiene-styrene, methacrylate-acrylonitrile-butadiene-styrene, acrylonitrile-butadiene-styrene, chlorinated polyethylene, ethylene-vinyl acetate, and acrylic. Acrylic processing aids are materials added to improve the processing characteristics of PVC and are typically used with impact modifiers. They accelerate the melting process and improve the rheological and mechanical properties of the melt. Processing aids are usually copolymers of methyl methacrylate and other acrylates.

Lubricants are added to resins to improve the flow characteristics of the plastic during processing. They function by reducing melt viscosity or by reducing adhesion between the metallic surfaces of the processing equipment and the melted polymer. Polarity, melting point, and solubility in the resin are key considerations when a lubricant is selected. Lubricants that reduce molecular friction, thus lowering the polymer's melt viscosity and improving its flow, are referred to as internal lubricants. Substances that promote resin flow by reducing friction of the melt as it contacts the surfaces around it are considered external lubricants. In practice, however, all plastics lubricants exhibit internal and external effects. Major classes of lubricants include amides, esters, metallic stearates, waxes, and acids.

Ultraviolet stabilizers help plastics resist light degradation. UV radiation in the range of 290 to 400 nm is absorbed by polymers that contain chemical groups called chromophores. If the absorbed energy is not dissipated, bonds within the polymer are broken and a free-radical chain reaction is initiated, which causes discoloration, embrittlement, and eventual degradation of the polymer. Thus, most polymers designed for outdoor use need to be stabilized with additives that either absorb more UV light than the polymer itself or deactivate the harmful free radicals and hydroperoxides as they are formed.

Benzophenones and benzotriazoles are two widely used commercial products that do act as UV absorbers. Although hindered-amine light stabilizers and nickel-containing complexes are used as antioxidants, they are not effective screening agents for ultraviolet radiation. Instead they stabilize the resin via free-radical termination and excited-state quenching.

The ideal additive would absorb all UV radiation but no visible light. In practice, a compromise has to be made. If no color is desired in the product, some UV transparency must be tolerated, or, alternatively, yellow discoloration must be allowed to achieve maximum UV absorption.

they want a bumper that will last twice as long as it used to and that puts new demands on the polymers and additives that go into that bumper," he explains.

"Clearly, new automotive systems are raising demands for additives," adds Hall's Hopper. For example, growth in the use of driver-side air bags has created the need for a plastic cover that can deploy very quickly without tearing and work under a very broad range of temperatures. This is a performance-driven application that represents a fast-growing niche for certain plastics additives, he notes.

Another existing market for additives that is creating some new challenges and opportunities is the polyurethanes business. Companies like Hall are anxious to develop new additives that may help polyurethane producers in their quest to "selectively extract" market share from those markets in which PVC and rubber are now dominant, says Hopper. With this market focus in mind, Hall is supplying polyurethane producers with a proprietary line of Urethhall polyester polyols that unlike traditional products, are not based on adipic acid. These new polyols allow polyurethane producers to achieve new performance properties so that they can compete with softer materials like rubber or more rigid plastics such as PVC.

Although polyurethanes are more expensive than PVC or rubber, this new grade meets higher performance standards and is more durable. For example, polyurethanes formulated with new polyester polyols can be used to make print rollers (such as those used in newspaper printing) that last longer than those made of rubber and PVC. "The polyurethanes business is one of the faster growing businesses we deal with, posting volume growth rates of roughly 10%," adds Hopper.

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Several additives may be used in a single plastic resin

	Antioxidant	Antistat	Blowing agent	Catalyst, peroxide	Catalyst, polyurethane	Flame retardant	Heat stabilizer	Impact modifier	UV stabilizer	Lubricant	Processing aid
ABS		●	●			●	●	●		●	●
Acrylic		●	●	●		●				●	
Epoxy		●		●		●	●	●		●	
HDPE		●	●	●		●		●		●	●
LDPE		●	●	●		●		●		●	●
Nylon		●	●			●				●	
Polycarbonate		●	●			●		●			
Polyester, thermoplastic		●	●	●		●		●			
Polyester, unsaturated		●	●	●		●		●		●	
Phenolic				●		●				●	
Polypropylene		●	●	●		●		●		●	●
Polystyrene		●	●	●		●		●		●	
Polyurethane		●				●	●	●		●	
PVC		●	●	●		●	●	●		●	●

Source: SRI International estimates

Expanding into new applications is something that Ciba-Geigy is also trying to do with its hindered-amine light stabilizers (HALS). In 1990, HALS accounted for 38% of the total volume of light stabilizers sold in the U.S.; the other major types of light stabilizers include benzophenone and benzotriazole, according to a study done on light stabilizers in April of this year by Phillip Townsend Associates. HALS, which were developed many years ago by Ciba-Geigy, are efficient at low concentrations and can be used in a broad range of polymers, especially polypropylene and low-density polyethylene. The continued growth of HALS will depend not only on application growths but also on the fact that they are being used to replace benzophenones. Ciba-Geigy has been successful in replacing benzophenones with HALS in most resins. However, cost and performance considerations likely will continue to drive benzophenone use in PVC, notes the Phillip Townsend Associates report. That's because resins containing halogens or sulfur are extremely incompatible for use with HALS.

Developing alternative products designed to meet anticipated or existing legislation is one route to business expansion that many additives producers are taking. Environmental pressures facing additive producers represent an opportunity for growth, says Butch Hite, business manager for the polymer additives and specialty monomers business unit at Eastman Chemical.

Clearly, this kind of opportunity exists in the heat-stabilizers market. Driven by legislative action and concerns by users about health risks associated with several commonly used products, consumption patterns of heat stabilizers used in plastics likely will change significantly during the next five years, according to a Phillip Townsend Associates' study. The payoff could be significant for additive producers that are poised to meet those changing needs.

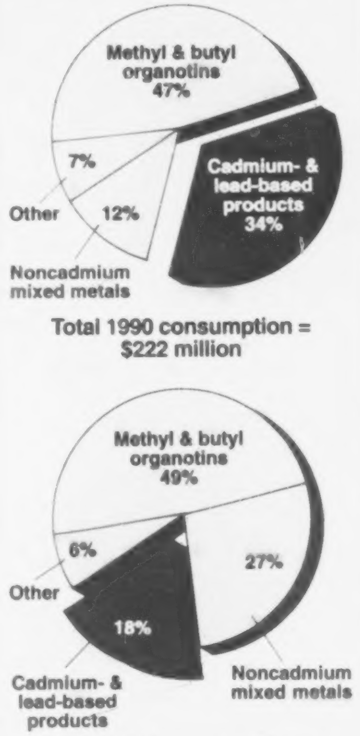
According to this study, more than $200 million worth of heat stabilizers were consumed by the U.S. plastics industry in 1990. "However, a more important point to consider," says Joel Kopinsky, research analyst with Phillip Townsend Associates, "is that lead- and cadmium-containing stabilizers, which are under increasing scrutiny for health and safety reasons, accounted for more than $75 million of the business."

The overall heat-stabilizer business is expected to grow at a healthy rate of 4% annually through 1995, net of any price increases, notes the Phillip Townsend Associates study. However, because cadmium and lead stabilizers likely will be replaced with competitive products, certain subsegments of the market will grow at more than 40% per year during the same period. "These developments will create problems for some suppliers but opportunities for others," reports Peter Gavrushenko, vice president of the consulting firm.

The pressure for reducing the use of cadmium- and lead-containing products is coming from many sources, including legislation proposed by state and federal agencies. For example, the Occupational Safety & Health Administration has issued a Notice of Proposed Rulemaking that will significantly reduce the permissible exposure limit for cadmium. In addition, a new risk assessment study on lead toxicity is expected within the next few years.

Connecticut, Iowa, Maine, New Hampshire, and Wisconsin have already passed heavy-metal reduction laws, and similar legislation is imminent in Pennsylvania and New Jersey. Sen. Harry Reid (D.-Nev.) has introduced a bill requiring the Environmental Protection Agency to ban or limit the use of lead in products for which substitutes are available. In addition, EPA has proposed revising standards for drinking water to reduce allowable cadmium from 10 to 5 μg per L. Cadmium and cadmium compounds are on California's Proposition-65 toxic chemical list that prohibits any discharge of cadmium into drinking sources. Outside the U.S., the European Community (EC) has followed the lead of Denmark, the Netherlands, Sweden, and Switzerland by proposing a ban on cadmium-containing stabilizers.

Cadmium-, lead-based heat stabilizer use will shrink



Note: Percentage of dollars.
Source: Phillip Townsend Associates

Anticipating the passage of more legislation, Witco's Argus Division is moving to phase out its cadmium-containing and lead-containing stabilizers "as soon as possible. Realistically, we hope to have 50% replacement of those products by the end of this year, but it depends almost completely on our customers' demands," says Victor R. Struber, Argus' director of marketing. "We can't move any faster than they are willing to evaluate these new materials."

At the same time, Argus has taken an aggressive approach toward developing and marketing alternative stabilizers. The division has introduced its Mark 4700 line of liquid noncadmium heat stabilizers, which are used in nonflexible PVC, and its Mark 6700 series of materials to replace its solid cadmium stabilizers, some of which go into PVC for electrical insulation end uses. "We are doing no new development work with anything but the noncadmi-

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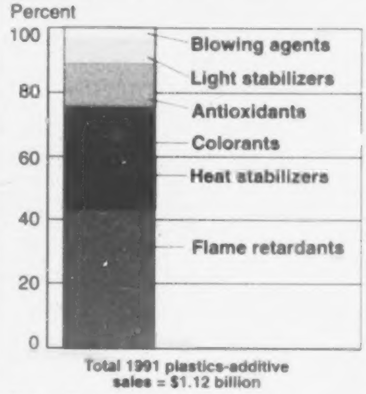
OAc
HF
$O=C-CH_3$
OH
+
$O=C-CH_3$
OH

Flame retardants are most used plastics additive



Source: Frost & Sullivan

ums in the mixed-metal area," says Struber. Mixed-metal stabilizers, which include both cadmium and noncadmium stabilizers, primarily go into flexible PVC or plasticized PVC used for shower curtains or wall coverings, for example.

In addition to its move away from cadmium stabilizers, Argus just completed a 50% capacity expansion for methyl organotin stabilizers at its Taft, La., facility. The major application for these products is in processing rigid PVC used in construction for siding, door and window frames, and pipe.

In addition, last October, Witco formed a cooperative technical and marketing agreement with Ciba-Geigy Marienberg, the wholly owned German subsidiary of Ciba-Geigy Ltd. in Basel, Switzerland. Under the agreement, the Argus Division and Ciba-Geigy Marienberg will share technical information and cooperate in the development of mixed-metal stabilizers for the PVC market. "We are excited by the opportunities afforded us with this agreement," adds Nirmal Jain, a Witco vice president and general manager of the Argus Division. "Witco has been on the leading edge of the development of mixed-metal stabilizers, and we believe the additional resources now available to us will increase our technical and marketing strengths. We are especially interested in pooling our technology with Ciba-Geigy in noncadmium PVC stabilizers."

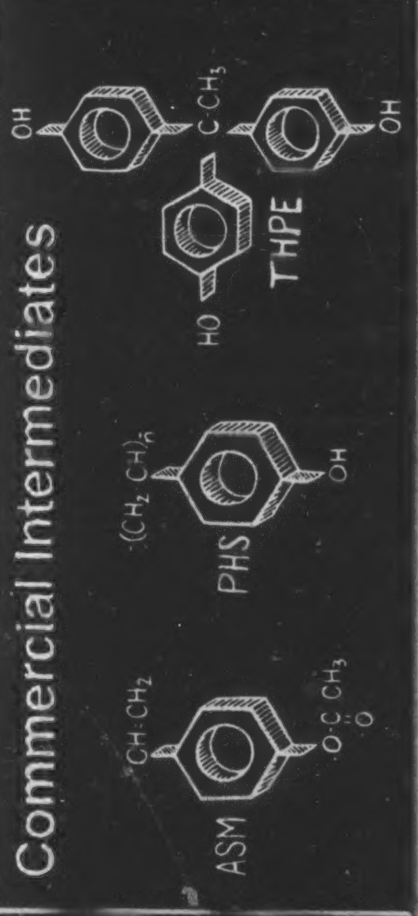
Concurrently, Witco entered into a marketing agreement, which excludes North America and Japan, with Ciba-Geigy Marienberg for methyltin stabilizers produced by Argus. "This venture increases our market penetration worldwide," says William E. Mahoney, Witco vice president, "while providing technology to sustain growth in the years ahead."

While Ciba-Geigy cooperates with Witco in the development of alternative stabilizers, it has its eye on some other regulatory issues as well. The company's U.S. pigments division has been developing pigments free of heavy metals to be in compliance with the Coalition of Northeast Governors (CONEG) in advance of the deadlines that were set by the coalition. CONEG has mandated that in all packaging, trace levels of four heavy metals—lead, hexavalent chromium, mercury, and cadmium—must be limited. It has proposed limits on the presence of these metals to 600 ppm one year after enactment of the legislation, 250 ppm two years after the enactment, and 100 ppm four years after the enactment. Thirteen states have passed laws limiting the levels of these four heavy metals and 13 more have introduced similar laws.

In response to this growing legislative effort, the pigments industry has sought to develop environmentally friendly pigments for bright, stable colors free of the four CONEG heavy metals and other potentially toxic or carcinogenic substances, says Eva M. Vary, director of product safety for Ciba-Geigy's U.S. pigments division. Developing pigments that are free of heavy metals but that have the same high opacity, heat stability, light fastness, and low cost of heavy-metal-containing pigments has been a challenge for researchers.

Ciba-Geigy says it has met this challenge. Nine of every 10 products in the company's U.S. pigments line are free of heavy metals; the others contain complex metals in insoluble form. This is important to Ciba-Geigy's pigment customers, says Vary, "because most packagers are currently requiring them to obtain certification that trace levels of the four heavy metals are below 100 ppm, exceeding current CONEG laws."

CONEG targeted the packaging industry when it discovered that containers and packaging constituted more than 30% of the solid waste generated in this country, raising fears that heavy metals in these products were entering



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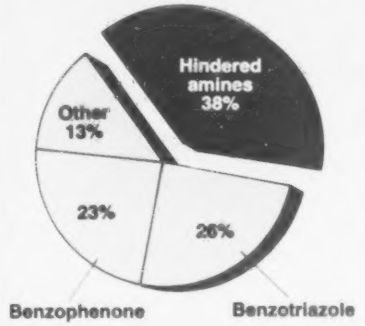
Hindered amines take 38% of light-stabilizer market



Total 1990 sales = $162 million

Note: Percents are by volume.
Source: Phillip Townsend Associates

the groundwater through landfills containing incinerator-ash residues and entering the atmosphere during incineration. Indeed, the plastics industry has also been affected outside the packaging area because heavy-metal pigments have been widely used in many plastics applications.

Helping pigment users make the transition to alternative pigments and sometimes alternative technologies requires more comprehensive support at all levels than ever before, says Vary. "We have to work closely with our customers to help them integrate the new products into their existing processes economically."

The possibility of regulatory phaseout is also looming large over another additive class—halogenated flame retardants. The jury is still out on whether that phaseout will come to pass. Some companies are busy developing and touting alternative products, whereas producers of halogenated flame retardants continue to defend the safety and efficacy of their products.

Some additive producers, such as Alusuisse-Lonza's Martinswerk Group, Bergheim, Germany, say traditional flame retardants based on halogen and phosphorous compounds cause the formation of toxic and corrosive decomposition products during their flame-retardant reaction, thus causing significant secondary damage. The company says recent investigations in Germany and the U.K. showed that more than two thirds of the fire deaths that occur every year are caused by inhalation of smoke and toxic gases and not by contact with fire. On the basis of these findings, Roman Nykyforuk, Lonza's director of marketing in its inorganics group, speculates that regulations limiting or possibly banning the use of brominated flame retardants could develop in Europe, and like so many other regulations have done, migrate to the U.S. legislative system.

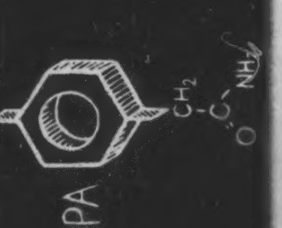
"But that possibility is remote," says John McChesney, a marketing communications manager for Ethyl. In a position paper on brominated flame-retardant regulatory and safety issues, Ethyl, a producer of these products, points out that no regulation is in effect anywhere around the world banning the use of brominated flame retardants, although regulations have been proposed. In Europe, a regulation was proposed that would limit the use of brominated diphenyl oxides in several European countries, but this regulation has been blocked by the EC. One reason for the block, Ethyl points out, is that the U.K. is concerned that the proposed directive would increase the hazard from accidental fires since adequate substitutes do not exist for all uses of the diphenyl oxides. Outside the EC, a few individual European countries have proposed legislation dealing with these products, but nothing has yet been passed.

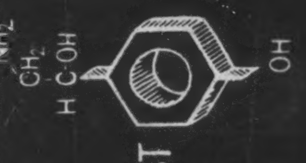
In the U.S., EPA has proposed testing several flame retardants, in-

U.S. plastics additives demand will grow roughly 4% annually through 1996

Millions of lb	1980	1991	1996	2000	% annual growth rate 1980–91	% annual growth rate 1991–96
Fillers	3615	5,750	7,180	8,225	4.3%	4.5%
Plasticizers	1325	1,770	2,000	2,190	2.7	2.5
Reinforcements	575	925	1,100	1,250	4.4	3.5
Flame retardants	393	690	905	1,040	5.3	5.6
Colorants	283	507	610	695	5.4	3.8
Impact modifiers	70	140	170	195	6.5	4.0
Other	283	448	535	605	4.3	3.6
TOTAL	**6544**	**10,230**	**12,500**	**14,200**	**4.1%**	**4.1%**

Source: Freedonia Group





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cluding decabromodiphenyl oxide (DBDPO), for health and environmental effects, but Ethyl anticipates that no decision on the final contents of the rule will be reached before early 1993. EPA also required testing DBDPO, along with a number of other brominated and chlorinated products, for dioxin and furan content. However, it discovered that no analytical method was available to meet EPA's limit of quantification and isomer specificity requirements, so an extensive, three-year methods development program was undertaken to meet these requirements. The analytical difficulties have recently been solved and results are anticipated sometime in 1992.

Ethyl says it is confident its products will come up clean. "Analytical results to date indicate DBDPO should not [cause] brominated dioxin-furan contamination," the company adds. Many toxicological studies have been conducted on DBDPO and show it has a "wide margin of safety. The many toxicological studies available on DBDPO are one of its advantages—much is known about its toxicology and the product has many years of safe industrial use," the company notes.

Ethyl continues to bank on growth for brominated flame retardants. The firm is "currently adding what will amount to $50 million worth of new capacity for several of our brominated flame retardants" at the Magnolia, Ark., facility, says McChesney. Within that project, Ethyl is quadrupling capacity for its proprietary Saytex BT93W product used primarily in styrenics. Despite concerns about the products, Ethyl anticipates demand for brominated flame retardants will be spurred partly by growth in demand for high-impact polystyrene, which is being used increasingly as a cost-effective replacement for acrylonitrile-butadiene-styrene, says McChesney.

For its part, Lonza maintains that the threat of halogenated flame-retardant legislation alone has boosted demand for flame retardants such as aluminum trihydrate (ATH) and magnesium hydroxide, which are halogen-free, nontoxic, and noncorrosive. The flame-retardant reaction for these products is based on endothermic decomposition of the hydroxides to the corresponding oxides and water, thus no toxic or corrosive gases are formed in the case of fire, says the company.

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CONFERENCE ON CHEMICAL RESEARCH XXXVI
REGULATION OF PROTEINS BY LIGANDS

October 26-27, 1992
THE WESTIN OAKS HOTEL, HOUSTON, TEXAS

MONDAY, OCTOBER 26

RICHARD J.V. JOHNSON, President, Welcoming of Guests
WILLIAM N. LIPSCOMB, Introductory Remarks

SESSION I
WILLIAM N. LIPSCOMB, Presiding Chair

SPECIES ADAPTION OF THE ALLOSTERIC REGULATION OF HAEMOGLOBIN
MAX F. PERUTZ

ACTIVITY AND ALLOSTERIC REGULATION IN GLYCOGEN PHOSPHORYLASE
LOUISE N. JOHNSON

SESSION II
MAX F. PERUTZ, Presiding Chair

ACTIVITY AND ALLOSTERIC REGULATION IN BACTERIAL PHOSPHOFRUCTOKINASE
PHILIP R. EVANS

ACTIVITY AND ALLOSTERIC REGULATION IN FRUCTOSE 1, 6-BISPHOSPHATASE
JIIN-YUN LIANG

TUESDAY, OCTOBER 27

SESSION III
ROBERT HUBER, Presiding Chair

ACTIVITY AND ALLOSTERIC REGULATION IN ASPARTATE TRANSCARBAMYLASE
WILLIAM N. LIPSCOMB

ALLOSTERIC EFFECTS IN THE ASPARTATE RECEPTOR
DANIEL E. KOSHLAND, JR.

LUNCHEON, 1992 WELCH AWARDEE

CLUSTERS, CHEMISTRY AND NANO TECHNOLOGY
RICHARD E. SMALLEY

SESSION IV
DANIEL E. KOSHLAND, JR., Presiding Chair

ALLOSTERIC EFFECTS IN RecA PROTEIN
THOMAS A. STEITZ

ALLOSTERIC EFFECTS IN PROTEIN SUBUNITS AND AT PROTEIN MEMBRANE INTERFACES
ROBERT HUBER

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Technician at Ciba-Geigy measures the melt flow index of an extruded polymer

Aiming to take advantage of the trend toward using these alternative products, in May Alusuisse-Lonza dedicated a new facility in Austria, a joint venture with Veitscher Magnesit, for the manufacture of its new magnesium hydroxide product called Magnifin. The magnesium hydroxide product "complements our Martinal ATH product line because it has a higher thermal stability so that it can be applied in polymer systems up to 340 °C," says Nykyforuk. This will allow the company to expand into other markets such as polypropylene and nylon. Its Martinal ATH is only suitable for use as a flame retardant in PVC and polyethylene, which are processed at lower temperatures.

Although regulations are presenting opportunities, additive producers are quick to point out that the proliferation of industry rules is also having a negative effect on their business. The spiraling number of regulations affecting the additives business "is a problem we all face as producers. And I don't deny the need for it," says Hüls' Magram. "The basis for the regulations being promulgated is correct, but regulators need to be driven less by emotion and more by science."

More regulation means that companies are being forced to spend more capital and human resources on compliance. "Five years ago we had one person in regulatory affairs, now we have three. It's a huge overhead expense," says Hall's Hopper.

Regulators are becoming overly stringent in their inspection processes, say many additive suppliers. For example, at one time the aromatics content of plant effluents was considered to be too high "if you could smell it," but now regulators are testing for those chemicals at the parts-per-billion level. "It's clearly much more difficult to run a plant now than it used to be," says Hopper. The bottom line is that "it's getting more difficult to meet market needs as more and more materials are being monitored at ever lower levels," he adds.

In the course of upgrading their plants, companies are also improving their facilities' environmental profiles. Within the next couple of weeks, American Cyanamid will announce expansion and modernization of its plant in Willow Island, W.Va. The project centers around light-stabilizer and antioxidant production, but will also involve work to reduce emissions substantially, according to American Cyanamid's Avrin.

In addition to affecting how additives producers' plants are run, an increasing number of regulations are also affecting the rate at which new products are introduced. The greatest pressure additives producers now face is the rising cost of new product development and new product introduction, says Avrin. "At Cyanamid, we have a range of products that offer unique performance advantages in niche markets, but with the continued rising costs of environmental compliance and product registration, it is becoming more difficult to expect that new specialty products can absorb all these costs and still be competitive in the marketplace against well-established products that might not even be as effective."

Hopper predicts many companies in the business today will not be in business five years from now because of "regulatory shutdown." "The smaller companies can't cope. These regulations may allow only the large to survive."

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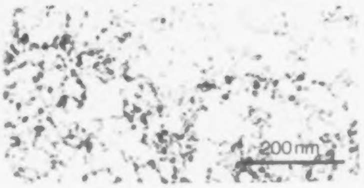

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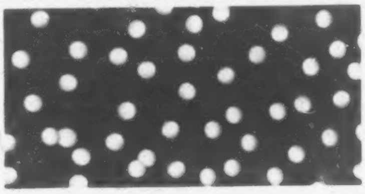

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CIRCLE 22 ON READER SERVICE CARD

Recycling may increase demand for additives

One of the biggest issues affecting the plastics business now is that of recycling. The industry is facing increasing pressure from the public and environmental groups to step up its role, but numerous technical and logistical problems stand in the way of widespread recycling.

Recognizing this, plastics additives producers say they have been looking for ways to help plastic recyclers solve these problems and thereby open up new niches for their expertise and products. But for the most part, additive producers report that their involvement in furthering the recycling effort is premature.

"Right now the problem for recycling is more physical—how to collect and segregate," says Allan Kushins, director of marketing for the functional chemicals group of Lonza, Fair Lawn, N.J. "Where there is a challenge [that calls for use of additives], the additives are not any different than the ones used for virgin resin. We'd really like to be part of [recycling efforts], but we don't see a role for the additives business right now," he adds. "It's not the additive producers that are going to be the driving force, its the resin producers. We'll work very closely with them, but they'll need to tell us their requirements."

Another limiting factor for additive producers: The recycling effort is just getting off the ground for plastics, such as polyvinyl chloride, that rely heavily on additives, notes John Dellevigne, executive vice president of Hüls' plastics division. The most commonly recycled plastics, polyethylene terephthlate and high-density polyethylene (HDPE), need relatively few additives.

Still, it's hard for additive producers to ignore the market considering that, by the year 2000, 6% of the total U.S. polyolefin market will be recycled, says Larry D. Rosenberg, a consultant with ChemSystems, Tarrytown, N.Y. Even from a small base of additives consumption, the market for additives used in recycling HDPE, polypropylene, low-density polyethylene, and linear low-density polyethylene will be sizable, he adds. "Recycled polyolefins are susceptible to degradation during compounding and melt reprocessing. This requires, in some cases, adding more antioxidants to prevent viscosity changes and discoloration. The trend is to err on the side of additional antioxidants during recycling."

The good news for additive producers is that as the recycling effort becomes more mature, they may be able to play a bigger role. Recognizing that, producers say they want to be ready to meet that demand. "It is definitely something we are working on, although we don't yet have any specific new products and nothing is commercial yet," says Avron Magram, vice president and general manager for the plastics additives and specialty lubricants group at Hüls America. "It is an exciting new business that could eventually open up opportunities for new additives."

One challenge to additive producers, Magram says, is developing products that disperse and mix in well with recycled material. Mixing additives into granular recycled plastic is more difficult than mixing them into a virgin plastic in a powder form, he notes.

Another opportunity for additives producers is developing antioxidants or plasticizers that not only "do the original job in the virgin resin" but also remain in the resin and continue to work as it is recycled, eliminating the need to add more. But selling that "add-on" processibility benefit to resin producers may prove to be difficult, says William Avrin, vice president and general manager for polymer additives at American Cyanamid. The resin manufacturers must pay an additional first application cost for this benefit even though they may not be handling

Indeed, the extremely fragmented plastics additives market is expected to become somewhat more concentrated as companies shut down or are bought out by larger producers. As in many fragmented industries, much of the plastics additives business is already concentrated in the hands of a few large companies. In 1991, the five leading firms—Ciba-Geigy, Akzo Chemical, Ethyl, Great Lakes Chemical, and Witco Chemical—accounted for 36% of the total market for plastics additives, according to a report on the U.S. market for plastics additives by consulting firm Frost & Sullivan, New York City.

The number of plastics producers is shrinking as well. As the larger U.S. resin producers acquire companies, a greater proportion of them are based outside the U.S. And while resin producers expand their geographic focus, additive producers say they must also globalize their business in order to compete. "It's hard to sell to a company like H. B. Fuller, 3M, or Du Pont if you cannot distribute your products and provide customer service outside the U.S.," says Hopper. "Every additive producer that wants to compete today must have a distribution channel that's global."

End-user companies and automobile companies in particular are becoming more global and are looking for "single sources" able to supply across broader geographic boundaries, notes Allan Kushins, director of marketing for Lonza's functional chemicals group. "For example, if a European automobile company comes into the U.S., they are looking for the same supplier that sells them the product in Europe. And the same holds true for U.S. end users. So our product goes from here to Europe for the same reason."

Another driving force behind the globalization of the plastics and additives businesses is the opening up of trade boundaries. "I think remarkable things will happen if the new trade agreements [with] Mexico and Canada are finalized," says Hopper. For example, "Much of what's now made in Southeast Asia, such as urethane-based shoes and apparel accessories, will be made in Mexico within the next five years," he predicts.

In anticipation of trade barriers coming down in Europe and North America, Witco has been making a concerted effort to become more global and to take advantage of the resultant opportunities, says Struber. Just last month, for example, Witco signed a definitive agreement to purchase the industrial chemicals and natural substances divisions from Germany's Schering A.G. The businesses will augment Witco's plastics additives business as well as others. William R. Toller, chairman of the board and chief executive of Witco says, "This acquisition represents a significant move toward making Witco a the resin when it is recycled. "It's too early to tell whether we will be able to market these [recyclability] advantages."

When more recyclers start to recycle a heterogeneous stream of postconsumer plastics into finished products such as park benches, "then plastics additives will become interesting and necessary" says Hüls' Dellevigne. A recent study by Houston-based Phillip Townsend Associates, says, "The greatest area of potential for compatibilizers is in recycling of plastics." In fact, by 1995 Phillip Townsend Associates forecasts that recycling will account for more than half the demand for compatibilizers.

Although few, if any, additives producers have yet to develop or market anything novel to recyclers, many companies are responding to their customers' environmental concerns in another way—offering their products in recyclable or returnable packaging. "There's been a lot of interest and activity in this area during the past six to 12 months," notes John McChesney, a marketing communications manager for Ethyl, which is providing some of its additives in these types of packaging.

"Nobody wants to send product packages into landfills," says Janet Crawford, business manager for additives in Akzo's polymer production chemicals group based in Chicago. "Our customers are aware of that and we're obviously aware of that. It fits in with the product stewardship, cradle-to-grave aspect of the Chemical Manufacturers Association's Responsible Care initiative. We want to take care of our products and packaging the whole way through." Akzo is considering shipping more of its additive products in packages such as supersacks, which reduce packaging, or in returnable totebins and liquibins. It is also looking into use of recyclable fiber drums.

Likewise, at its new granulation, blending, and packaging unit at its McIntosh, Ala., production site, Ciba-Geigy has built in advanced capabilities for providing customers with environmentally preferred packaging options, says Paul Simonetti, a marketing communications manager for the company's additives and pigments division. For example, some of the company's antioxidants are available in 1200-lb bulk containers, or recyclable 44-lb polyethylene bags, all designed to reduce or eliminate packaging waste.

In addition, Ciba-Geigy now packages antioxidants for polystyrene production in a totally consumable bag. The result of a collaborative development effort among Ciba-Geigy; Bonar Inc., Burlington, Ontario; and A.V.P. Extrusions Ltd., Newcastle, Ontario, the package is a rubber-modified polystyrene package that can be added into the polystyrene production process along with the antioxidant without any effect on the process. Using the polystyrene bag requires no additional equipment or expense for the manufacturer, says Simonetti. A special Food & Drug Administration-approved ink is used on the package—it does not affect chemical reactions occurring during polystyrene production, says the company. The new package avoids the environmental problem of disposing of bulky packaging such as fiber drums. At the same time, it provides a convenient way to incorporate Ciba-Geigy's Irganox 1076 FF granular antioxidant into the process.

The consumable bags are not the best solution for all resin producers. "Some of our customers don't want to throw the polyethylene bags we use into the process because they like to have stringent control over the final quality of their product," says Crawford. "They want to know the history and source of everything that goes into their final product including what the bag is made of and who made it."

global chemical company by doubling our international revenues." Witco's technical and marketing agreement with Ciba-Geigy Marienberg in the stabilizer area is another move aimed at increasing its market penetration worldwide, Struber points out.

Ethyl is another of the many additives suppliers that says it is broadening its participation in markets outside the U.S. For its part, the company is slated to complete a new technical center at Leouvain-la-Neuve, Belgium, by early 1993. Eastman Chemical Co., too, is expanding its sales and technical service efforts to support worldwide growth, says Hite.

Meanwhile, other companies are reshuffling their internal divisions in an attempt to gain more clout on a global basis. For example, in an effort to promote Lonza's corporate identity as a global supplier of additives and processing aids to the plastics industry, late last year the company formed a plastics marketing team. The new team, which is made up of representatives from the company's functional and inorganic chemicals groups, will emphasize the worldwide commitment to the plastics industry by the Alusuisse-Lonza Group of companies, of which Lonza is a part. The new group aims to unify and market internal and external lubricants, antistats, antifogs, flame-retardant additives, compatibilizers, graphite, carbon additives, and more, in one focused effort.

As the plastics additives business becomes increasingly global, producers must work even harder to keep up with technology on a worldwide basis. "There's no question that the additives business is becoming more global, in a technical sense," says John Dellevigne, executive vice president of Hüls' plastics division. "It used to be that developed countries had locks on certain types of process and formulation technology. But now you have companies in places like India or Malaysia that are up to speed on the latest available plastics technology. As a result, it's tough for a company to keep an edge with an advantageous formulation or product. The world finds out about it and develops an alternative that's just as good. So today, products are becoming more similar around the world. Advantages in the plastics business are short-lived."

Still, there are many new problems to be solved with new technology and that fact is what makes many producers "bullish" on the outlook for the plastics additives business. Says Magram of Hüls: "I am wildly enthusiastic about the potential for growth for plastics additives. All plastics have performance deficiencies and a key way to overcome them is to use additives. Those challenges continue to crop up faster than we can solve them and they all represent new opportunities for growth." ☐

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C&EN
SEPTEMBER 7, 1992

ICI HEADS LIST OF GLOBAL TOP 50 CHEMICAL PRODUCERS PAGE 17

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Meeting the challenge
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CHEMICAL & ENGINEERING NEWS

C&EN

SEPTEMBER 7, 1992

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- Giant fullerene cages are formed by coalescence of hot, dense C_{60} and C_{70} vapors in research that may open up new routes to synthesis of large fullerenes. **Page 6**
- UN Conference on Disarmament sends landmark chemical weapons treaty to UN General Assembly for approval in October. **Page 6**
- In next three weeks, NASA plans to launch space shuttle bearing spacelab that will carry out 43 microgravity experiments, and Mars Observer spacecraft to explore the Red Planet. **Page 7**
- In response to caterpillar attack, corn plants activate systemic chemical defense that releases volatile terpenoids, attracting parasitic wasps to kill the caterpillars. **Page 8**

BUSINESS

Sales of global Top 50 chemical producers dip 2% to $314 billion as a result of 1991's stronger dollar, slow sales, and weak prices; U.K.'s ICI ranks at top of list. **Page 17**

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Deteriorating polymer objects in museums challenge chemists to develop methods to preserve plastic and synthetic fiber artifacts, ranging from old lace to space suits. **Page 27**

Water appears to be an important source of hydrogen and oxygen in geochemical formation of petroleum. **Page 30**

First Hirschfelder Prize in Theoretical Chemistry is awarded to Cornell's Benjamin Widom. **Page 31**

Vanderbilt University symposium honors J. C. Martin for his 40 years of contributions to the field of chemistry. **Page 32**

Microwaves can remove sulfur dioxide and nitrogen oxides from stack gases resulting from coal combustion. **Page 32**

ACS NEWS

Photographs capture variety of activities at ACS national meeting in Washington, D.C. **Page 46**

Graduate school fair is just one highlight of national meeting programs for undergraduate chemistry students. **Page 48**

SPECIAL REPORT

Strong growth is likely in the 1990s for environmental catalysts that reduce air pollutants such as carbon monoxide, volatile organic compounds, and nitrogen oxides, as the result of recently enacted amendments to the Clean Air Act. Page 34

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COVER: Catalyst microspheres exit calciner at 2100 °F; such catalysts for fluid catalytic cracking will help petroleum refiners meet requirements of Clean Air Act. Photo courtesy of Engelhard

Volume 70, Number 36
CENEAR 70 (36) 1–66
ISSN 0009-2347

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
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(202) 872-4600; TDD (202) 872-4432
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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
(For list of offices see page 65)

Office of Ombudsman: (800) ACS-5558, No. 8–5

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LETTERS

Political science

After reading the lead article "Big Science Funding: Big wins for SSC and space station" (C&EN, Aug. 10, page 3), I have to say that C&EN overlooked something that all the other media overlook. The title misleads the reader into thinking that either the Superconducting Super Collider or the space station is big science. They are more rightly big engineering, something quite different, and if science results from either, that is a bonus.

As to my support for either, I tend to side with the cancellation crowds, but for entirely different reasons, as far as I can tell. In principle, I like both. But these "gigaprojects" have been driven too heavily by politics at the expense of engineering and science, taking secondary and tertiary roles, respectively. The debate, as portrayed in most media, resembles a trial in which both sides send their expert witnesses to do battle. One side claims the large spin-off potential, the other, the waste of scarce federal dollars on a project of questionable benefits. The peer-review process—a better, if still less than perfect, process by which we best judge science—gets scrapped. Insofar as this represents the norm, it should trigger alarm bells.

For instance, when the SSC-siting process took place around the last Presidential election, major political players included George Bush, James Baker, Lloyd Bentsen, Phil Gramm, Ann Richards, the late John Tower, and Jim Wright. (Please note both Democrats and Republicans in this list.) Should anyone be surprised that the SSC landed in Waxahachie, Tex.? If Paul Simon (Senator, not singer) had been the Democratic Presidential candidate with Dan Rostenkowski (very hypothetical) as his running mate, would the SSC have been located at Fermilab, a site arguably superior to Waxahachie? (No, I have never even been to the Chicago area, other than inside O'Hare Airport.) I do not know, but I suspect that it would have been better situated, politically that is. But whatever the outcome, such political interference taints the scientific endeavor. Moreover, in terms of expected discoveries and particle production, the present SSC design promises less than the original version that garnered such widespread scientific and political support. In this sense, the phrase "bait-and-switch" comes to mind.

Similarly, space station *Freedom* receives much political backing from the National Space Council, located in the Old Executive Office Building where its chairman works. When one considers that such space council leadership nicely pads the political résumé of a potential Presidential candidate, one should not be surprised that the space station will not die easily (if at all), even (or perhaps especially) in its virtually scienceless form.

If these examples typify federal science to come, the science and engineering communities had better preempt further procedural deterioration of federally funded science by devising an open review process that both safeguards scientific integrity and sustains political support without sending the unwelcome message: We know science; trust us with [y]our federal dollars.

David L. Wagger
AAAS Science, Engineering, and Diplomacy Fellow
Arlington, Va.

Leave it to the experts

The letter by H. A. Kjellman, entitled "Science Cacophony" (C&EN, June 1, page 3), deplores that many contradictory voices claim truth on scientific matters, creating a "modern-day Tower of Babel." It is my purpose to draw a little map of Babel.

Within the confines of this letter, let us divide the world into scientists or "experts," and nonexperts. The media and the publicists informing the public about scientific matters are expert in journalism, TV, and communication but generally nonexpert in science. Even if they comprehend, their audience or their agenda requires simplification beyond expert recognition. The public is eager to know but likewise generally nonexpert in science. Can nonexperts communicate an alien expertise?

Although Descartes is not popular with the media, I will slightly rearrange a Cartesian dictum (Discourse on Method, Part I): Nonexperts, ignorant of mathematics and logic, base their arguments upon authorities that are ancient and outmoded. Although including the best

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Shifts in Rankings, Losses Mark Global Top 50 List

Global group's 1991 sales dip to $314 billion, a 2% drop from 1990, as business, political climates curb industry

Patricia L. Layman, C&EN London

This year's annual C&EN ranking of the world's 50 largest chemical producers shows that 1991 was a year marked by slowing sales and weak prices that put a dent in operating profits, by a strong dollar compared with the year before, and by some shifts in rankings including one dramatic tumble.

The global listing uses the same criteria as C&EN's ranking of the 100 largest U.S. chemical producers (C&EN, May 11, page 13). Wherever possible, it excludes formulated products such as coatings, pharmaceuticals, consumer products, and nonchemical operations such as specialty equipment and energy.

Chemical sales rung up by the Top 50 companies in 1991 totaled $314 billion, a decline of about 2% from 1990. Several factors accounted for the decline: the relatively strong dollar, for one, adversely affected chemical sales translated into dollars, especially when compared with the effect that that same conversion had on balance sheets in 1990. Another factor was the continuing shift in company portfolios to higher value-added formulated products—such as pharmaceuticals, coatings, and detergents—that lowered the actual chemical sales.

In 1991, moreover, external factors added hurdles. The first half of the year, for example, was marked by the war in the Persian Gulf. Disruption of markets and production were primarily the cause of the 34% decline in sales shown by Saudi Basic Industries in 1991 from 1990, a tumble that dropped the company out of the Top 50 altogether.

If slowing economies were starting to curb sales, then overcapacity—a growing global problem—began having a serious adverse effect on the selling prices of a host of chemical products in 1991. Producers of petrochemicals and other basic chemicals felt the impact of this effect most severely, with operating profit margins shrinking. Two producers—the U.K.'s BP Chemicals' and Norway's Norsk Hydro's chemicals operations—had operating losses for the year, and the picture was only slightly better, albeit profitable, at a number of other petrochemical producers.

Overcapacity—a growing global problem—began having an adverse effect on chemical selling prices

German chemical companies—six of the Top 50, including three of the five largest—account for 21% of the total sales, $65.4 billion. The U.S. continues to have the largest number of companies among the 50, at 15. However, that is a decline of one from last year, and a drop of three from two years ago, when C&EN began its rankings.

Although Europe as a block fields the largest number of companies (24) in the Top 50, the largest individual nation represented in the rankings, next to the U.S., is Japan, with 11 companies on the list. The same 11 companies are on the list this year as last year, but several have advanced in the standings. Moreover, their share of total chemical sales has risen to 15% of the total, or $48.2 billion, from 14% the year before.

The 1991 list shows Union Carbide at 22nd, down from 13th in 1990. The drop reflects the company's split into Union Carbide and the industrial gases supplier Praxair, which would be placed on an expanded listing at number 51. Similarly, because U.K.'s ICI has announced that it is considering a split in its operations—a split virtually certain to take place—into ICI, a chemical company, and ICI Bioscience (C&EN, Aug. 10, page 5), next year's listing undoubtedly will reflect a major change at the very top.

The British chemicals giant has been working to increase the percentage of its sales accounted for by higher value-added products, such as pharmaceuticals and coatings. Notwithstanding that continuing effort, however, ICI has emerged as the largest producer in the C&EN rankings with a higher percentage of chemical sales than any of its four major competitors—BASF, Hoechst, and Bayer of Germany, and Du Pont of the U.S.

Should the split proceed as expected, ICI, by C&EN criteria, still would be solidly among the 10 largest producers, but no longer in the top five. ICI Bioscience probably would not make the cutoff for the Top 50 ranking.

In many respects, the ICI action simply will take to extremes the portfolio reshuffling going on throughout the chemical industry—companies trying to sell "noncore" operations, so as to devote resources and attention to a controlled number of businesses. Although other mega-chemical producers might find the idea of a split appealing, in many cases, the tax law and other laws of individual countries might make such a course of action totally impossible. German tax law, for example, would make a split such as that proposed by ICI impossible.

Stock market analysts accept the existence of such strictures, but only reluctantly. Very rarely, they argue, do the synergies once fashionably cited as encouraging a company to maintain various chemically related interests re-

Chemical sales of global Top 50 total more than $300 billion

Rank 1991	Rank 1990		Chemical sales ($ millions)	Chemical sales as % of total sales	Chemical operating profits ($ millions)	Chemical operating profits as % of sales
1	3	ICI (U.K.)	$18,127	77.6%	$ 621	3.4%
2	1	BASF (Germany)	17,951	63.8	1081	6.0
3	2	Hoechst (Germany)	17,825	62.7	814	4.6
4	4	Bayer (Germany)	16,066	62.9	690	4.3
5	5	Du Pont (U.S.)	15,383	39.8	1265	8.2
6	6	Dow Chemical (U.S.)	13,277	70.6	835	6.3
7	8	Shell (U.K., Netherlands)	11,239	10.9	41	0.3
8	7	ENI (Italy)	10,817	26.4	62	0.5
9	10	Rhône-Poulenc (France)	9,422	63.4	472	5.0
10	12	Ciba-Geigy (Switzerland)	9,268	62.9	599	6.5
11	9	Exxon (U.S.)	9,171	7.9	512	5.6
12	11	Elf Aquitaine (France)	8,865	24.9	559	6.3
13	14	Asahi Chemical^a (Japan)	7,249	100.0	218^b	na
14	15	Veba (Hüls) (Germany)	6,183	29.4	81	1.3
15	17	Monsanto (U.S.)	5,451	61.5	694	12.7
16	19	British Petroleum (U.K.)	5,423	8.2	–12	—
17	20	Mitsubishi Kasei^a (Japan)	5,408	100.0	40^b	na
18	16	Akzo (Netherlands)	5,347	59.3	230	4.3
19	24	Sumitomo Chemical (Japan)	5,214	100.0	113^b	na
20	18	DSM (Netherlands)	4,998	98.6	337	6.7
21	21	Solvay (Belgium)	4,996	67.2	355	7.1
22	13	Union Carbide^c (U.S.)	4,877	100.0	599	6.5
23	26	Sekisui Chemical (Japan)	4,833	100.0	158^b	na
24	22	General Electric (U.S.)	4,722	7.8	803	17.0
25	25	Norsk Hydro (Norway)	4,703	49.6	–33	—
26	—	Air Liquide (France)	4,688	83.1	na	na
27	23	Occidental Petroleum (U.S.)	4,649	40.4	53	1.1
28	—	Henkel (Germany)	4,580	59.0	243	5.3
29	—	BOC^d (U.K.)	4,531	90.0	628	13.9
30	29	Toray Industries^a (Japan)	4,455	100.0	202^b	na
31	30	Showa Denko (Japan)	4,289	100.0	1^b	na
32	31	Takeda Chemical^a (Japan)	4,171	100.0	241^b	na
33	28	Mobil (U.S.)	3,953	6.3	245	6.2
34	27	Amoco (U.S.)	3,893	13.8	56	1.4
35	35	Dainippon Ink & Chemicals^a (Japan)	3,848	100.0	59^b	na
36	36	Roche (Switzerland)	3,817	47.7	na	na
37	33	Eastman Kodak (U.S.)	3,740	19.3	538	14.4
38	34	W. R. Grace (U.S.)	3,531	58.4	426	12.1
39	—	Total (France)	3,227	12.7	264	8.2
40	39	Unilever (U.K., Netherlands)	3,172	7.7	393	12.4
41	40	Mitsui Toatsu Chemicals^a (Japan)	3,140	100.0	53^b	na
42	37	Chevron (U.S.)	3,098	7.7	196	6.3
43	41	Mitsubishi Petrochemical^a (Japan)	3,025	100.0	115^b	na
44	43	Arco Chemical (U.S.)	2,837	100.0	398	14.0
45	44	Rohm & Haas (U.S.)	2,763	100.0	327	11.8
46	42	Degussa^d (Germany)	2,762	34.3	na	na
47	46	Air Products^d (U.S.)	2,676	91.3	474	17.7
48	—	Nobel Industries (Sweden)	2,621	64.2	198	7.5
49	—	Montedison (Italy)	2,618	20.7	293	11.2
50	50	Teijin^a (Japan)	2,522	100.0	111^b	na

Note: Listing includes chemical sales only, so as to facilitate comparison with C&EN's Top 100 list (May 11, page 13). Excluded where possible are formulated products such as coatings, pharmaceuticals, and adhesives, and specialty equipment, energy, and other nonchemical operations. **a** Fiscal year ends March 31. **b** Net profits. **c** Following split into Union Carbide and Praxair. **d** Fiscal year ends Sept. 30. **na** = not available.

ally work to the advantage of the shareholder. On the other hand, the higher profit margins shown by many U.S. chemical companies, earned in an environment less constricted in terms of buying and selling businesses, do filter through to the shareholder.

Analysts also argue that, to some extent, there may be a natural limit to the size of an effectively managed company that provides good value to shareholders. No one wants to put a number on that limit, which would vary in any case. But small- to medium-sized companies, they insist, are more able to move quickly, make more sensible business decisions, and know their markets and customers better than the management of very large companies.

Says one mergers and acquisitions specialist: "One of the things we've found we've had to deal with is half a dozen people, rather than just one decisionmaker. In the big companies, people often just don't know what's going on—the quality of the management, whether a business is truly profitable, and so on. They often make crazy business decisions that will never be repaid."

In some businesses, of course, size is crucial. There is less room in the petrochemical industry for smaller producers, for example, because of the sheer size of capital investment required for new projects. To establish a stake in the pharmaceuticals business or agricultural chemicals sector also takes significant investment in research and development.

All too frequently, however, economies of scale also bring pitfalls such as layers of management and loss of flexibility to customize service and orders. That can mean opportunity for the small- to medium-sized company, such as those with sales rosters between $1 billion and $2 billion, many of which are located in the U.S.

Splitting up of entire companies is relatively rare, but selling off operations while snapping up small strategic acquisitions is well on its way in the U.S., and is being seen more frequently in Europe. However, because of the general state of the global economy, points out one stock analyst, "it's an odd market at the moment. People want to sell their noncore businesses, but they don't want a cheap price."

No fire sales, not many bargain prices. And bar an extraordinary example like ICI, not that much change in the cards for next year's Top 50 ranking. ☐

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CHEMICAL & ENGINEERING NEWS
C&EN
SEPTEMBER 14, 1992

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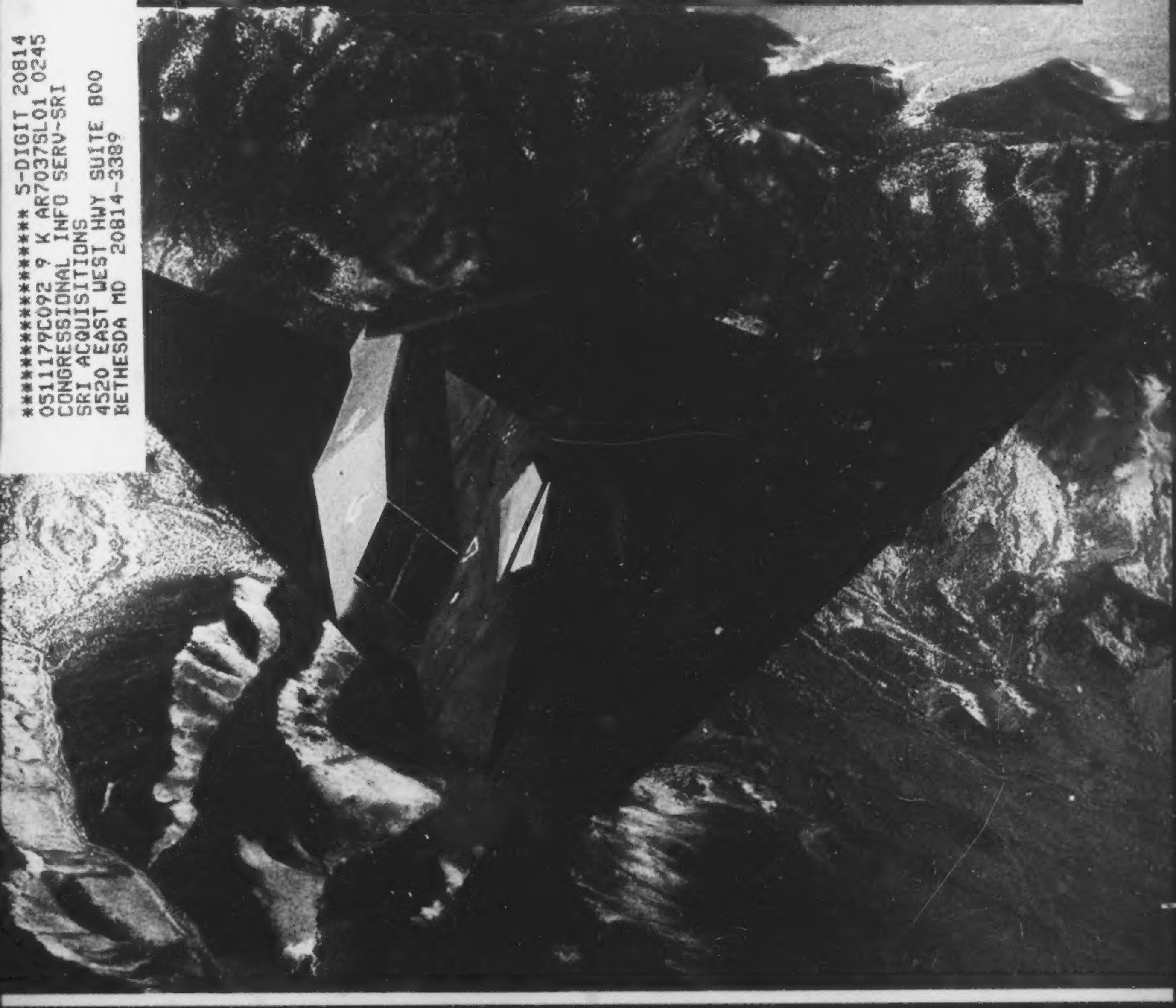

DARPA

Key defense research agency probes limits of the possible

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NEWS OF THE WEEK

- Neilsbohrium, hassium, and meitnerium are formally proposed as names for heavy elements 107, 108, 109, but naming procedure and names of other heavy elements are causing controversy. **Page 4**
- Dow Chemical announces executive changes: Paul Oreffice will retire in December, Frank Popoff will succeed him as chairman, and, next April, William Stavropoulos will follow Popoff as president. **Page 5**
- Two Texas companies consider building major chemical plants in Mexico—one to produce methyl *tert*-butyl ether and another to make linear alkylbenzene. **Page 6**
- Joan Shields withdraws from ACS Board election, leaving a field of four candidates for the two available director-at-large spots. **Page 6**
- University of California and California State University systems face dramatic funding cuts of 11% and 9%, respectively, as a result of tightened California State budget. **Page 6**

COVER: F-117 stealth fighter developed by Lockheed with initial DARPA support. Photo courtesy of Air Force

Volume 70, Number 37
CENEAR 70 (1) 1–60
ISSN 0009-2347

BUSINESS

Productivity in the chemical industry rose more than 7% in the second quarter and unit labor costs fell almost 4%, seeming to signal the end of the recession. **Page 21**

Germany's Bayer can't use its tradename in the U.S. as a result of an injunction issued by a judge in New York. **Page 22**

GOVERNMENT

Macroeconomic policies haven't considered environmental damage resulting from development programs for developing countries and thus are responsible for their ecological decline, charges think tank report. **Page 26**

Very stringent rules for pesticide registration are being considered by the European Community, but European agrochemical industries are lobbying hard to weaken them. **Page 27**

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600, TDD (202) 872-4432
John Kistler Crum, Executive Director
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PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman*: Joseph A. Dixon; *President*: Ernest L. Eliel; Richard L. Deming; Judith C. Giordan; William P. Jencks; and Gary J. Long

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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
(For list of offices see page 59)

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Canadian GST Reg. No. R127571347

LETTERS

CHEMICAL SAFETY

Explosion with MoO_5·DMPU complex

With the discovery of the ability of the oxodiperoxymolybdenumhexamethylphosphoramide complex (MoOPH) to oxidize enolate anions to α-hydroxy ketones [*J. Am. Chem. Soc.*, **96**, 5944 (1974); *J. Org. Chem.*, **43**, 188 (1974)] has come widespread use of this reagent. More recently, James C. Anderson and Stephen C. Smith, in an effort to replace the toxic HMPA ligand, have recommended its substitution by the noncarcinogenic 1,3-dimethyl-3,4,5,6-tetrahydro-2-(1*H*)-pyrimidinone (DMPU) [*Synlett*, **2**, 107 (1990)]. Indeed, in our experience, this modified reagent, for which the acronym MoOPD has been proposed, is entirely comparable to MoOPH in its efficacy. The two reagents are prepared similarly. In the latter case, MoO_3 is treated with 30% H_2O_2 at 40 °C, cooled to 10 °C, and complexed to 1 equivalent of DMPU. The resulting solid, MoO_5·DMPU·H_2O, is recrystallized from methanol at 40 °C, and dehydrated at 0.5 torr over P_2O_5. The resultant solid is then dissolved in tetrahydrofuran and treated with 1 equivalent of pyridine to give MoOPD.

Recently, we had occasion to transfer the dried MoO_5·DMPU (about 70 g) into a round-bottomed flask in preparation for its dissolution in THF. This transfer had been performed many times before without incident. On this occasion, the student attempted to facilitate passage of the solid through the attached funnel with a stainless steel spatula. A violent explosion resulted with complete destruction of the glassware. The operator received extensive cuts to his face, arms, and torso. The safety glasses he was wearing clearly prevented damage to his eyes.

Oxodiperoxy complexes should therefore be invariably treated as shock-sensitive materials and handled behind appropriate safety equipment.

Leo A. Paquette
Dongsoo Koh
Ohio State University

Mercury vapor release from Kjeldahl digests

We would like to comment on David Lewis' letter (C&EN, Aug. 10, page 2) concerning mercury vapor release from Kjeldahl digests during distillation. It should not be surprising that this occurs, because a sodium thiosulfate-sodium hydroxide mixture under elevated temperature would certainly contribute to mercury metal formation. The surprising aspect of Lewis' comments is that the standard procedure continues to require mercury salts at all.

A large number of mercury-free catalyst preparations, which are composed of nontoxic components, are commercially available. In most cases, the preparations consist of a transition metal (usually a copper salt), an organic matrix decomposing agent (peroxides or titanium dioxide), and potassium sulfate (for boiling-point elevation). Our experience with the mercury-free systems is that they yield better recovery of total nitrogen with shorter digestion times compared with the mixtures that contain mercury metal or mercury salts. In fact, our direct experience with the determination of nitrogen in polyvinylpyrrolidone (a pharmaceutical excipient) has resulted in the change of the official U.S. Pharmacopeia monograph procedure to incorporate the use of a $CuSO_4$-TiO_2-K_2SO_4 catalyst mixture. We strongly suggest that Lewis alert the Environmental Protection Agency to the safety hazards associated with the standard test and recommend use of a mercury-free preparation. Although correlation data will certainly be required to confirm the validity of the modified test, such a test will be infinitely safer to use and will most likely have faster digestion times.

Robert M. Ianniello
Section Manager, Analytical Department
International Specialty Products
Wayne, N.J.

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Major Change in Offing for DARPA, Key Defense Research Agency

If Congress has its way, the Defense Advanced Research Projects Agency will be directed to pursue more dual-use technologies

Lois R. Ember, C&EN Washington

In 1958, the Soviet Union launched Sputnik and sent a technologically surprised U.S. into a tailspin. Sputnik's unexpected existence sparked scientific and technologic revitalization in the U.S. civilian and defense sectors. Earth's first man-made satellite, in particular, spawned a small, still little known, but highly innovative agency, now called the Defense Advanced Research Projects Agency (DARPA).

DARPA is the Department of Defense's (DOD) pivotal research and development organization. Sen. Jeff Bingaman (D.-N.M.) calls it "the crown jewel in the defense research establishment, and one of the most successful agencies in the entire federal government." But the jewel is sparkling less brightly these days, and Bingaman is offering legislation to polish it up.

Simply stated, the agency is charged with making certain that the U.S. never again faces a technological bombshell, and that the individual armed services are equipped with the most sophisticated, state-of-the-art communications and weapons systems. DARPA director Gary L. Denman describes the agency's mission as "exploring the limits of the possible." He proudly notes that "almost every weapons systems that was used [in the Persian Gulf War] could trace its origin to DARPA."

DARPA's most recent formal mission statement calls for it to conduct "imaginative and innovative R&D projects offering significant military utility." Moreover, the statement directs the agency to be daring and risk-taking. Basic and applied R&D projects should "exploit scientific breakthroughs and demonstrate the feasibility of revolutionary approaches for improved cost and performance of advanced technology for future applications."

However, some believe DARPA has been asked to interpret its mission too narrowly, excluding—to the impairment of DOD and the nation—work on dual-use technologies that have high potential utility in the commercial, as well as military, sector.

Denman: agency explores limits of possible

Once DARPA was renowned for being ahead of the curve in solving exotic problems. Historically, it has strongly influenced technological developments in the civilian sector. Commercial spin-offs of its work have included the computer mouse, packet switching that allows more than one personal computer to be used in the same network, and new lightweight composite materials used in skis and tennis rackets.

But in recent years, DOD has gone from being a leader in advancing technology to a follower. It has become increasingly dependent on developments in the civilian sector. However, because of its management style and contracting procedures, DOD has found it more and more difficult to gain access to developments in the civilian sector.

Lewis M. Branscomb, director of a science policy program at the John F. Kennedy School of Government at Harvard University and former chief scientist at IBM, calls this trend the ghettoization of the defense establishment. He argues that, to its detriment, the U.S. has developed two separate technological cultures: one military, the other civilian. But, "as the defense budget declines, the government will become more dependent on access to an increasingly sophisticated commercial high-tech industry. This suggests that commercial and defense programs need to share a common technological base," he says.

To prevent a downward spiral in national security, and to bolster economic competitiveness, Bingaman has introduced a bill designed to "integrate defense and commercial technologies into a strong, unified, national technology base." His bill would accomplish this by expanding DARPA's charter to focus more heavily on dual-use technologies without sacrificing agency support for technologies of purely defense importance.

Bingaman and his supporters contend that dual-use technologies—electronics, software, new materials—are becoming a major factor in basic technologies crucial to the military. These very same technologies are also central to economic

Military, civilian sectors target similar technologies. . .

MILITARY (Defense Department)	CIVILIAN (Commerce Department)
Composite materials	**Advanced materials**
Machine intelligence and robotics	**Artificial intelligence**
Software productivity	**High-performance computing**
Data fusion	**Digital imaging technology**
Photonics	**Optoelectronics**
Semiconductor materials, advanced semiconductor devices	**Microelectronic circuits**
Biotechnology materials and processes	**Biotechnology**
Superconductivity	**Superconductors**
Passive sensors	**Sensor technology**

. . .but cultures of the two show dissimilar traits

IMPETUS FOR DESIGN

Civilian: **Market-driven, opportunistic introduction of new products**
Military: **Dictated by military requirements**

NATURE OF RESPONSE

Civilian: **Rapid, incremental improvements, punctuated by more basic redesigns**
Military: **"Big leap" improvements**

PRODUCT CYCLE

Civilian: **Measured in years**
Military: **Measured in decades**

PRIORITIES

Civilian: **Process technology for low-cost manufacturing, high quality, flexibility**
Military: **Product technology for functional performance, long shelf life**

PRODUCTION

Civilian: **High production rates and volumes**
Military: **Low production rates and unit volumes**

INTEGRATION OF R&D WITH PRODUCTION

Civilian: **Integrated management of R&D, production, customer service**
Military: **R&D and production separately contracted for, sequential**

TECHNOLOGY SHARING

Civilian: **Success based on proprietary technological advantage**
Military: **Success may require sharing know-how with second-source contractor**

Source: G. L. Epstein and A. B. Carter in "New Perspectives for a Changing World Order," American Association for the Advancement of Science, 1991

competitiveness in a world where leading-edge technology is likely to be developed in the private sector and probably outside the U.S.

As Bingaman notes, "Even though defense and commercial products continue to diverge from one another, the supporting technologies are converging." By fostering dual-use technologies, DOD probably will gain faster and cheaper access to commercial technology. And the civilian sector will likely benefit from additional federal support.

The Senator's bill, S. 2517, has been approved by the Senate Armed Services Committee as part of the fiscal 1993 defense authorization bill, which at press time was being debated on the Senate floor. There are no provisions for expanding DARPA's mission in the already-approved House version of the authorization bill, but the Bingaman provisions will likely be accepted by the House-Senate conference committee for inclusion in the final fiscal 1993 defense spending bill, says Edward McGaffigan Jr., a Bingaman aide.

As now constituted, DARPA is a lean, mean research machine that insists on taking the long view with a "focus on scientific breakthroughs and revolutionary approaches," director Denman explains. It vigorously and consistently pursues concepts that change in very fundamental ways how military systems work. This contrasts sharply with the research programs of the Army, Navy, and Air Force, which generally strive for incremental changes to existing military systems.

With annual budgets hovering around $1.5 billion, DARPA is in a unique position of being "a very small fish in a very large pond," says Gerald L. Epstein, coauthor of the recently published book, "Beyond Spinoff: Military & Commercial Technologies in a Changing World." Although its budget is quite large compared with budgets for similar activities in the Commerce Department, for example, Epstein points out that DARPA's budget is less than 1% of the Pentagon's, its parent agency.

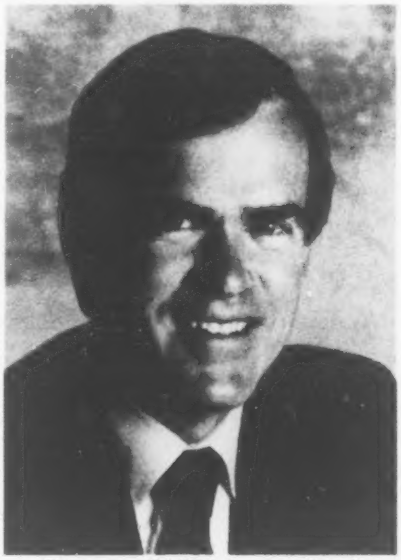
Because its budget amounts to mere paper-clip money for the Pentagon, DARPA has been able to operate fairly autonomously. "It's had the freedom to explore technologies that had no immediate application, without having a spotlight focused on every decision it has made," Epstein explains.

This freedom has even allowed the agency to underwrite the development of new industries, as it did with computers. It was an early and generous supporter of leading-edge R&D in the commercial computer industry for a very simple reason: The Pentagon, a major user of computers, would benefit as a purchaser of state-of-the-art products rapidly being developed in the commercial sector.

Although it sponsors path-breaking research, DARPA's 148 personnel do no research themselves. All projects are contracted out to industry and academic laboratories. And what makes the agency unique is that it is a self-contained contracting entity unburdened by the typical bureaucracy of other government contracting agencies. Emphasis is on speed, so the contracting process is unusually flexible and creative.

There are 10 technical offices within DARPA, each with its own director. These office directors report to DARPA director Denman, who in turn reports to Victor H. Reis, director of defense research and engineering and the immediate former head of DARPA. Denman is a civilian, chosen by the Secretary of Defense.

The key to DARPA's successful track record is the agency's 86 program managers who report to technical office directors. These 86 scientists and engineers ride herd on the cutting-edge basic and applied R&D projects that have produced the stunning technical breakthroughs for which the agency is noted—stealth technology that makes the F-117 fighter nearly invisible to radar, revolutionary new materials, and massively parallel computers. They plan research programs, award and manage project contracts, solicit promising ideas from industry and university sources and propose these ideas to agency directors, and keep current on the latest developments in their fields.



Bingaman: DARPA is crown jewel

The agency is not afraid to pursue what McGaffigan calls "wacky, but often fruitful ideas," but it does not pursue them indefinitely. Depending on the technology, DARPA will give a concept three to 10 years to prove out. If a technology fails to pan out, DARPA drops it and moves on to the next tantalizing possibility.

Contracts are awarded on a competitive basis. Frequently DARPA will pair research teams from industry and academia, on a cost-sharing basis, to bring an emerging technology to the prototype stage. DARPA's ultimate customers are the armed services, which often must be prodded from their parochial perches to be convinced of the need for, and effectiveness of, path-breaking technologies.

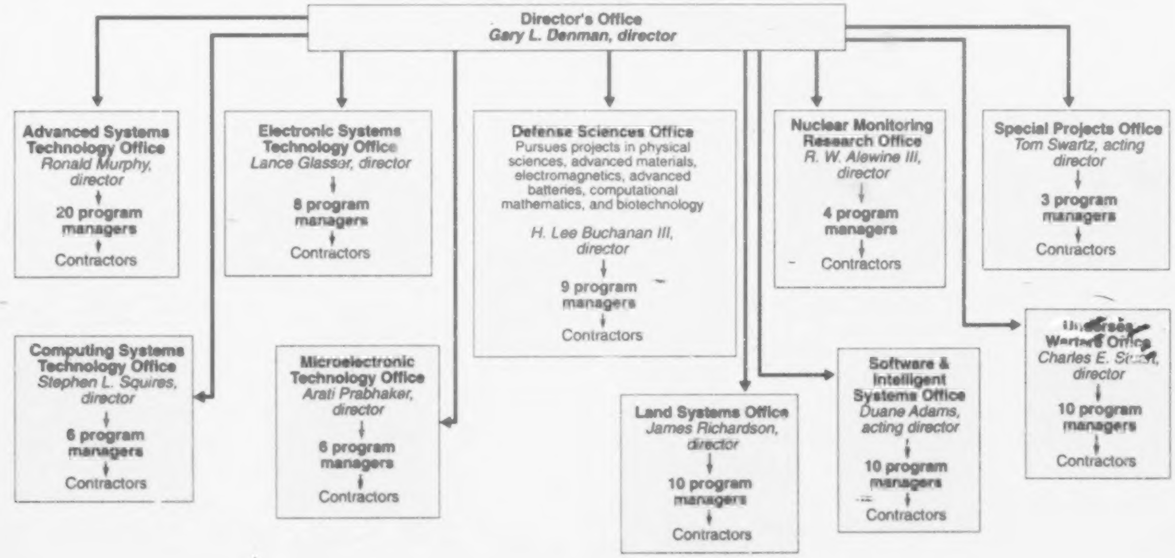
For the near future, the agency's R&D endeavors will focus on electronics, information technology, materials, and propulsion. Prime areas of emphasis in electronics include optoelectronics and electronic devices based on the so-called quantum-well phenomena, and high-temperature superconductivity.

The agency expects optoelectronics will offer novel interconnections for massively parallel computers (computers working separately but simultaneously, each on one part of a single problem), high-definition displays (the commercial version is high-definition television), and image processing free of electromagnetic interference. Quantum-well devices are expected to form the basis for ultrafast computing in the next century. Passive microwave components made from unique ceramic materials—the products of high-temperature superconductivity research—have already been inserted into existing electronic warfare systems.

According to Bingaman, "DARPA almost single-handedly created the discipline of materials science." Renee Ford, *Materials & Processing Report* editor, confirms that "DARPA was one of the most significant early and sustained supporters of all the major areas of materials science." Ford particularly cites the agency's support for research on the chemical laser and the chemical basis of ceramics.

DARPA's advanced composite materials program aims to produce lightweight, structurally sound materials able to

Key to DARPA are 86 program managers—nine oversee physical science, biotech projects


Director's Office
Gary L. Denman, director
Advanced Systems Technology Office
Ronald Murphy, director
20 program managers
Contractors
Electronic Systems Technology Office
Lance Glasser, director
8 program managers
Contractors
Defense Sciences Office
Pursues projects in physical sciences, advanced materials, electromagnetics, advanced batteries, computational mathematics, and biotechnology
H. Lee Buchanan III, director
9 program managers
Contractors
Nuclear Monitoring Research Office
R. W. Alewine III, director
4 program managers
Contractors
Special Projects Office
Tom Swartz, acting director
3 program managers
Contractors
Computing Systems Technology Office
Stephen L. Squires, director
6 program managers
Contractors
Microelectronic Technology Office
Arati Prabhaker, director
6 program managers
Contractors
Land Systems Office
James Richardson, director
10 program managers
Contractors
Software & Intelligent Systems Office
Duane Adams, acting director
10 program managers
Contractors
Undersea Warfare Office
Charles E. St[illegible]t, director
10 program managers
Contractors

operate in the high-temperature environments of jet engines, airframes, and missiles. Research on electronic materials has produced gallium arsenide, indium phosphide, and mercury cadmium telluride for high-speed signal processing and infrared imaging.

Even objects as mundane—though necessary—as batteries have been given the DARPA spin. By exploiting a breakthrough in the chemistry of conducting polymers, the agency has been able to build a pilot line for producing solid-state batteries with very high power density. The pilot line is producing these batteries using a continuous thin-film manufacturing process. According to Denman, the batteries can be recharged, have 100 times the shelf life of nickel-cadmium batteries, and are safe. They do not explode when heated, punctured, or short-circuited. They also can be molded into shapes that fit specific weapons systems.

Ep[illegible] spotlight on agency decisions

DARPA research in the area of high-performance computing is extensive, and the agency is a key player in the federal high-performance computing and communications program. Computing systems (and their supporting software) fundamental to the information revolution are on or just over the horizon. Gigaop systems, using 100 billion operations per second, are now emerging, and two such systems are ready to hit the commercial market, Denman says. Teraop systems, using 1 trillion operations per second, are expected by the mid-1990s.

Most recently, the agency has effected a major basic change in high-performance computing by developing scalable parallel computing. That didn't happen serendipitously. The agency has been developing and advancing computing technology since 1961, and has been responsible for such changes as time-sharing, computer graphics, computer networking, and personal computing.

To ensure that it has the materials and equipment for the manufacture of electronic components critical to defense, DARPA provides 50% of the operating funds for the nonprofit consortium called Sematech. Fourteen U.S. semiconductor firms and the more than 150 suppliers that compose Sematech provide up to 80% of the integrated circuits used in weapons systems.

This year, DARPA set up another seven cost-sharing consortia. The intent is for the Pentagon to share the financial burden with industry for military-critical technologies that neither the Pentagon nor industry wants to fund alone. DARPA has $60 million that it can apply to these consortia, which are positioned to develop technologies ranging from microelectronics for "smart" weapons to so-called stealth-measuring algorithms.

For various reasons, few expect that the agency will be able to duplicate its past success rate. According to Bingaman, a key factor to DARPA's earlier successes "was the agency's ability to fund visionary research with only indirect military applications." In its prime, DARPA project managers made commercial spin-offs a conscious objective.

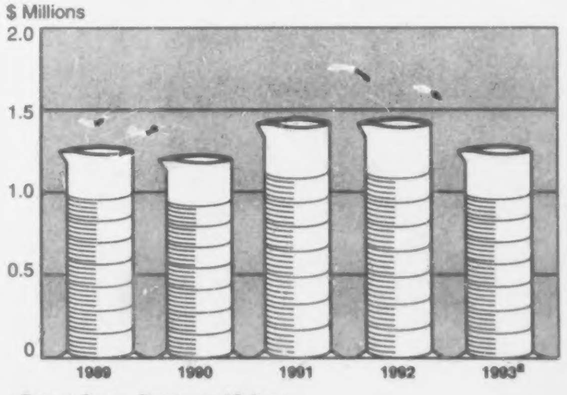
During the past two decades, however, budgetary distress has pressured the agency to focus on less visionary, more immediate applications and engineering. And in the past four years, free-market advocates in the industrial-policy shunning Bush Administration have decided that "DARPA should not support any technology with significant commercial application," Bingaman contends. The end result is predictable: "Support for dual-use technology has gone from being an ideal to a pejorative."

Several eminent groups have traced what they see as the U.S. decline in national security and economic prosperity to the government's disinterest in pioneering and fostering dual-use technologies. One such group, the Carnegie Commission task force headed by retired Admiral Bobby R. Inman, provided the basis for Bingaman's legislation.

The 1991 Carnegie report, "Technology & Economic Performance: Organizing the Executive Branch for a Stronger National Technology Base," concluded that "the Department of Defense and other federal agencies should have programs that enable their technology developments to serve commercial industry as well."

The Carnegie task force recommended DARPA be converted into a National Advanced Research Projects Agency (NARPA) that would more tightly link military needs and high-tech industry. Although retaining its main responsibility of servicing its key clients—the armed services—NARPA would help to create a national technology base, one that merged the now separate military and civilian technology bases. "Separate enclaves serve neither the commercial economy nor national security," the report concluded. Further, the commission urged that NARPA support

DARPA's 1993 R&D budget down 12%



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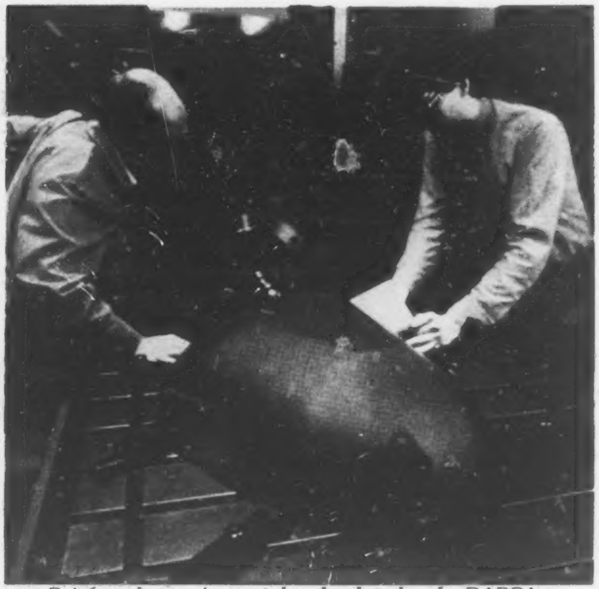


Reinforced ceramics, metals—developed under DARPA contract by Lanxide—are used in armored vehicle hatches

dual-use technologies as well as long-term, high-risk, generic technologies that have potentially high pay-offs.

A 1992 study by the National Academy of Sciences (NAS), "The Government Role in Civilian Technology," supports the Carnegie findings, urging "that DARPA's traditional role in dual-use technology be reaffirmed." The NAS task force, chaired by Carter Administration Defense Secretary, Harold Brown, stresses that the panel is not calling on DARPA to focus on technology developments that have strictly commercial applications.

In addition, Epstein's book, "Beyond Spinoff," warns that "the Pentagon cannot provide the best technology to the military services unless it breaks out of its enclave, learning to use technology spawned in the commercial sector and attracting capable high-technology firms willing to supply its needs."

Bingaman asserts DARPA is a prime, though not the only, mechanism for helping the nation regain its economic competitiveness and maintain its defense superiority. "DARPA's traditional operating style is well suited to a post-Cold War era in which DOD must increasingly access commercial technology and work with commercial firms." Bingaman adds that the agency has been relatively immune to Congressional micromanagement. "There has not been pressure on DARPA to support the politically powerful as opposed to the economically promising."

The legislation he has offered drops the word defense from DARPA's name, giving it back the name it had during its first 14 years of existence, but keeps ARPA within DOD. As envisioned, ARPA would continue to support technologies having unique military applications, but would direct increasing attention to development of dual-use technologies.

It would do this by reaching out to companies that have not traditionally worked with the Pentagon. To make this possible the bill would have ARPA work more collaboratively with these nondefense firms through the medium of cooperative agreements. Presently, DARPA uses contracts as the legal means of supporting research. And through these contracts, DARPA controls almost every decision about project management and technical objectives.

Bingaman says his bill does not dilute DARPA's military mission. "ARPA would remain a defense agency, connected to the needs of its defense customer, and subject to the authority, direction, and control of the Secretary of Defense." Further, he says, "the agency will continue to fund purely military R&D and continue to serve as the 'court of last resort' for leap-frog military technologies that the individual services choose not to fund."

He stresses that ARPA would not undertake research projects having purely commercial application, or "broaden its research purview to technologies without a potential military application." ARPA's defense mission would come first, but that mission would "require a national technology base."

Bingaman emphasizes that ARPA's existence would not "preclude the expansion of the Commerce Department's Advanced Technology Program, or the creation of other, ARPA-like entities in civilian agencies." In fact, he supports the NAS task force's call for the establishment of a $5 billion Civilian Technology Corp. (CTC), to be funded through a one-time Congressional appropriation. The thrust of CTC would be to increase commercialization of new products and processes. Under the CTC umbrella, the government would support precommercial technologies by creating joint ventures with private industry. By using CTC as a conduit, the NAS task force argues, there would be no interference with corporate management strategies or with market forces that drive economic growth.

Bingaman aide McGaffigan wants the thrust of the Senator's bill to be very clear: "We are saying that DARPA has an appropriate role in dual-use, generic, precommercial technologies in its areas of competence. We are not saying that DARPA should get more involved in the commercial sector than it has in the past, or get involved in areas that it has not traditionally been involved in, like environmental R&D."

There is now an "opportunity for synergy between the commercial and military sectors. And we should seize it," McGaffigan says.

Beltz: success will be undercut by dual-use push

Research chemist transforms idea into device with DARPA support

Imagine the memory capacity of a Cray supercomputer in a device the size of a sugar cube. University of California, Irvine, chemist Peter M. Rentzepis did. And along with engineering colleagues at the University of California, San Diego, he obtained funding from the Defense Advanced Research Projects Agency (DARPA) to transform his creative musings into a concrete 3-D memory cube—1 cm on each side—that one day will be capable of storing 1 trillion bits of information.

Not only is the memory device capable of storing a lot of information, it "has the potential of writing and reading billions of bits of information in thousandths of a second," Rentzepis says. Furthermore, it is easy to build and inexpensive.

The concept behind the 2-photon 3-D memory cube is beguilingly simple. A laser beam is split in two. Mirrors and lenses direct the two beams so that they intersect at right angles on one photochromic molecule within the cube. The combined energy of the two beams is absorbed by the light-sensitive molecule, changing it from colorless to blue. In computer language, using 0 and 1, this "write" molecule goes from a 0 bit to a 1 bit.

To read the stored information, another laser of a different wavelength is split in two, and made to intersect on the altered write molecule. The combined energy of the laser beams is absorbed by the blue molecule, causing it to fluoresce and emit a red light. Photodetectors sense the red flashes from this "read" molecule, and if the detectors are linked to a computer processor, the flashes can be converted back into bits of information.

Right now the patented experimental memory device consists of a polystyrene cube into which photochromic molecules have been dispersed. The light-sensitive molecule Rentzepis is currently using is a spirobenzopyran that goes by the moniker 5′-chloro-6-nitro-1′,3′,3′,-trimethyl-spiro-[2*H*-1-benzopyran-2,2′-indoline]. However, as the device is further researched and engineered, it is very likely the polymer matrix and the photochromic molecule will change.

Rentzepis and colleagues have shown that their experimental system works. A few bits of information have successfully been written, read, and "erased." But a lot more work needs to be done to transform the experimental device into a prototype that eventually can go into full-scale production.

One vexing problem is the stability of the spirobenzopyran in the written form—at room temperature it is retained only for minutes and in dry ice only for days. There appear to be at least two ways of solving this problem. "You could anchor the ends of the open read form" of the spirobenzopyran, "or you can look for new types of molecules such as intermolecular proton transfer molecules," Rentzepis explains.

Combining his many years of research on lasers with his more recent interest in optical computing enabled Rentzepis to make the intuitive leap

However, DARPA officials don't appear ready to do so. The agency's only official statement on the ARPA legislation comes from former director Reis. He told a Senate Armed Services hearing in April, "I believe that increasing the scope of DARPA beyond its current mission . . . as suggested by the Carnegie Commission will have a negative effect upon DARPA and its role." Bingaman largely based his ARPA legislation on the recommendations of this commission.

At a recent symposium on defense R&D and competitiveness, sponsored by the American Enterprise Institute (AEI), a Washington-based public policy think tank, a panel discussing DARPA's future mission agreed "that there is nothing that should prohibit DARPA from pursuing those technologies that are being driven by a clear military mission. And if there are commercial spin-offs, then that's fine, but that shouldn't be the up-front consideration," says AEI policy analyst Cynthia A. Beltz, who organized and participated in the symposium.

DARPA invests heavily in chemically related research

$ Millions	1993[a]	1992	1991
Materials science	$31.8	$42.7	$16.2
High-temperature superconductivity	22.7	26.5	25.3
Materials processing	18.2	78.9	57.2
Optoelectronics/ gallium arsenide	15.2	14.7	10.2
IR crystal growth technology	0	0	10.0

a Requested **Source:** Department of Defense

Panel member Theodore H. Moran, director of international business at Georgetown University, tells C&EN he is "not adamantly against expanding DARPA's role into dual-use targeting. But if we do so, we should permit foreign companies to be eligible to participate in DARPA's programs on a cost-sharing basis." That said, Moran still believes "a better way of strengthening civilian R&D, by far the more efficient and cost-effective way, is to expand the R&D credit."

Another panel member, David C. Mowery, professor of business administration at the University of California, Berkeley, tells C&EN "DARPA has been successful because it has been a small, lean agency with little middle management that has focused on a narrow profile of technologies. The danger it faces under the proposed legislation is being asked to fund programs in a much broader array of technologies."

Mowery insists that "DARPA is not the appropriate agency for the mission of improving economic competitiveness." Baker Spring, defense policy analyst at the Washington-D.C. based Heritage Foundation agrees: "DARPA is primarily a defense agency, and its mission is to put the best technology in the hands of fighting men. It should not be sidetracked into commercially competitive technologies if it comes at the detriment of its military mission." The mission for ARPA as outlined in the Bingaman bill "symbolically moves away from a focus on defense technologies, and that's ill-considered," Spring says.

Beltz contends that "the capabilities that made DARPA successful in

BEST AVAILABLE COPY

Rentzepis with prototype of memory cube device

from 2-D storage on magnetic disks to the theoretical possibility of more powerful 3-D storage in a plastic cube embedded with light-sensitive material. The much honored, 55-year-old chemist could have sought and probably would have received support to prove out his concept from several sources. But when he did seek support, Rentzepis went to DARPA, not the National Science Foundation.

He did so for several reasons, one being amount of support. DARPA has funded him to the tune of $1.5 million over three years, a contract that is coming to a close. This is more than NSF would have given him, he says.

Furthermore, NSF supports and encourages very basic science as an end in itself. DARPA, on the other hand, supports basic research but with the objective of some day having a viable, defense-related product. In Rentzepis' case, that product will be a computer storage device that will not be the rate-limiting factor in powerful optoelectronic computers and highly parallel electronic processors still to be developed.

"I'm not suggesting that basic science is not useful," Rentzepis contends. "But it is nice to see your own work becoming useful in your lifetime."

He and his San Diego collaborators have high expectations that their memory device contract will be renewed for another three years, allowing them to develop a prototype. Another DARPA contract under which Rentzepis "built what I think is the first picosecond x-ray lab system," has already been extended for one year.

Rentzepis has enjoyed doing basic, nonclassified research under DARPA contracts. "DARPA gives a sufficient amount of money [for carrying out the research], but is demanding, and I think that is right. The agency keeps close track of deadlines and the project as a whole," he explains.

DARPA is doing a vast amount of materials research. Because of this, Rentzepis "thinks it can be a good research home for a lot of chemists."

the past will be undercut by the push to dual use." Furthermore, she argues, "the agency was successful because it had a narrow agenda, and was a small, flexible agency with a great deal of independence. This independence could be jeopardized by increasing micromanagement by Congress. Dual use could be the mandate that opens the door for Congress to intervene in DARPA's internal decisions. It could be the back door for a wider competitiveness agenda." Moran expresses a similar concern: "I am wary that [the Bingaman bill] opens the door to pork-barrel Congressional pressures."

At the symposium, McGaffigan said that that wasn't a concern because DARPA in the past has been insulated from Congressional interference. But Beltz argued that "Congress has micromanaged DARPA by giving it *x* amount of dollars for *y* technologies." To which McGaffigan countered that Congress may have picked the technologies and the amount of support, but DARPA chose the projects and contractors.

Beltz's bottom line is simple. "The legislation in itself is not controversial." But she is not convinced that it will "work in practice in the tidy and measured manner proponents say it will, and not become a stalking horse for projects Congress wants, but the Defense Department doesn't."

She wonders if "it is realistic to expect DARPA to play the same role in the future as it did in the sixties as a technology incubator when we're in a world that is clearly 'beyond spin-off.' " What she is alluding to is the flow of technology from the civilian to the defense sectors, when in the past the flow was in the reverse direction.

"Beyond Spinoff" coauthor Epstein suggests "DARPA should not be the single government agency operating on civilian technologies." It is very possible, he points out, that the agency "may not be the vehicle for reaching the broad spectrum of industrial projects" that may be needed to promote global economic competitiveness, and that programs within the Commerce Department may provide the better route.

As DARPA moves toward the mission proposed for ARPA, "it may be less able to operate autonomously, as it has in the past, and it will certainly have to interact more closely with industry," Epstein says. "The risk for tighter Congressional oversight is real. There is a need to come up with some insulation that will allow the agency to retain its autonomy yet still have close contact and consultation with industry.

"I am almost certain that there is not a single institutional solution" for promoting both military security and economic prosperity, Epstein adds.

Despite all the qualms expressed, supporters of an expanded DARPA mission, like Ford, ask: "Why shouldn't we take advantage of projects DARPA has supported that have benefits for the civilian sector? Why shouldn't we get more bang for the buck?" These are the very questions addressed by Bingaman and his Congressional supporters.

Surprisingly, for a macho defense-oriented agency, DARPA is often described in such maternal terms as "technology incubator," and "nurturing environment." The consensus in Congress at the moment is that DARPA now needs to extend its protective mantle around dual-use technologies. ☐

Chemical Productivity Jumped In Second Quarter

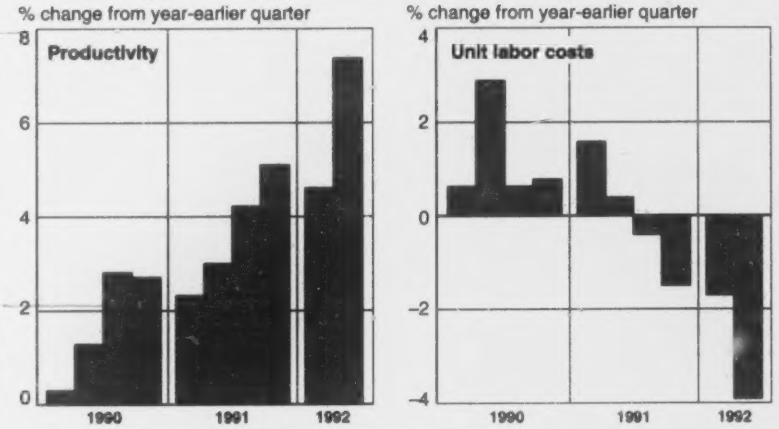
■ ***Increase of more than 7%, largest in years, was far better than that for all manufacturing; unit labor costs fell 3.9%***

A sharp rise in productivity in the second quarter seems to signal a post-recessionary period for the chemical industry. Typically, at or near the end of a recession, productivity rises quickly as increases in work forces, which were pared during the contraction, lag increases in output. The result is more units of product produced by fewer workers.

For instance, chemical productivity in 1983 climbed more than 8% over the previous year, marking the end of the early 1980s' recession. Similarly, productivity in the chemical industry jumped more than 10% in 1976 over that for 1975, the year in which the 1970s' recession ended. Productivity is defined as output per unit of labor, calculated by dividing the Federal Reserve Board's index for production by the Labor Department's index for aggregate weekly hours of production.

Productivity in the chemical industry, according to calculations by C&EN based on data from the Federal Reserve Board and from the Labor Department, increased 7.4% in the second quarter over the same period in 1991 to an index of 115.0 (1987 = 100) and was up 3.5% over the first quarter this year. This is far better than the productivity increase for the total manufacturing sector. Productivity for all manufacturing rose only 1.2% in the second quar-

Chemical productivity, unit labor costs both improved



Sources: Federal Reserve Board, Department of Labor, C&EN estimates

Second-quarter productivity improvement better for chemicals than for all manufacturing

	1992		1991				1990			
	2nd qtr	1st qtr	4th qtr	3rd qtr	2nd qtr	1st qtr	4th qtr	3rd qtr	2nd qtr	1st qtr
CHEMICALS AND ALLIED PRODUCTS										
Production	116.9	113.6	113.2	112.1	109.3	109.1	109.9	110.8	109.9	110.0
Workhours	101.0	101.6	101.3	101.0	101.4	102.1	103.4	104.0	105.0	105.3
Productivity	115.0	111.1	111.1	110.3	107.1	106.2	105.6	105.9	104.0	103.8
Hourly production wages	116.6	115.3	115.2	114.1	113.0	112.1	111.2	110.0	109.3	107.9
Unit labor costs	101.3	103.7	103.7	103.4	105.5	105.5	105.3	103.9	105.1	103.9
ALL MANUFACTURING										
Production	109.3	108.0	108.6	108.5	106.7	106.1	109.0	111.1	110.2	109.2
Workhours	102.9	102.6	102.5	102.5	101.7	102.1	104.4	107.4	108.0	108.1
Productivity	114.0	112.9	113.7	113.6	112.6	111.5	112.0	111.0	109.5	108.4
Hourly production wages	115.5	114.3	114.2	113.3	112.5	111.5	111.1	109.9	109.1	107.9
Unit labor costs	101.3	101.2	100.5	99.8	99.9	100.0	99.2	99.0	99.6	99.5

Note: Productivity is output per workhour, calculated by dividing indexes for production by indexes for workhours of production employees. Unit labor costs are labor costs per unit of output, calculated by dividing indexes for wages by indexes for output per workhour. **Sources:** Federal Reserve Board, Department of Labor, C&EN estimates ter to an index of 114.0 and was up less than 1% from the first quarter of this year.

The year-to-year productivity increase for the chemical industry in the second quarter, the largest in years, came on a 7% rise in chemical production over the year-earlier quarter. Workhours, which have trended downward since mid-1990, continued to decline, although at only a slight 0.4% from the previous year's second quarter.

One of the major reasons for the decline in workhours over the past two and a half years has been the cutback in employees at chemical companies (the index of aggregate workhours is a function of both the number of workers and the hours worked). Since the beginning of 1990, according to the Department of Labor, the number of production and nonsupervisory workers has fallen about 36,000, or almost 6%, on a seasonally adjusted basis. And for the first half of that two-and-a-half-year period, production was for the most part relatively flat, prior to picking up in mid-1991. Thus, since the second half of 1991, production has increased and the number of plant workers has continued to fall, increasing productivity on even its most basic level—the number of workers needed to turn out a particular product.

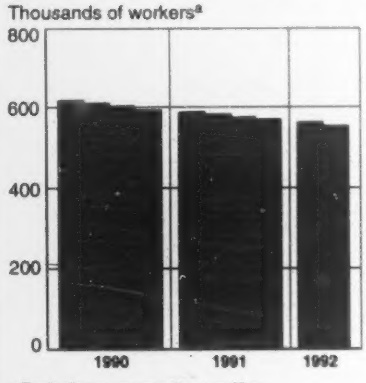
Like productivity, unit labor costs (the employee cost per unit of product) improved dramatically in the second quarter, falling 3.9% from second-quarter 1991 and down 2.3% from the first quarter this year. In contrast, unit labor costs for all manufacturing in the second quarter rose 1.4% from the year-earlier period and were essentially unchanged from this year's first quarter.

For all manufacturing, the second-quarter increase in unit labor costs came largely from a 2.7% increase in hourly production wages from second-quarter 1991 and a 1.0% rise from first-quarter 1992. The annual increase in wages thus far has outpaced the 1.2% rise in output per hour from last year's second quarter and was about the same as the 0.9% rise from the first quarter this year.

The improvement for chemicals, however, was due entirely to the 7.4% rise in productivity, which far outpaced the 3.2% increase in hourly production wages on a year-to-year basis. The increase in production wages in the second quarter was the lowest on a quarterly basis in the past two and a half years, with the exception of the 2.9% increase in the first quarter of this year.

William Storck

Rolls of chemical production workers down 6% since 1990



a Production or nonsupervisory positions.
Source: Department of Labor

Bayer barred from using tradename in U.S.

With the stroke of a pen, a judge in New York has essentially made Germany's Bayer—the fourth largest chemical producer in the world—into a noncompany in the U.S.

A U.S. District Court judge for the Southern District of New York has issued a final injunction that prohibits Bayer A.G. or any of its subsidiaries from referring to the Bayer trademark name in the U.S. in any but the most restricted circumstances. The injunction not only limits Bayer's use of the name in the U.S., but also restricts the use of the name outside the U.S. where advertisements or news reports originating from Bayer or its affiliates overseas may make their way into the U.S. market.

The injunction leaves the German chemical producer, which had $25.5 billion in worldwide sales in 1991, bereft of its identity in the U.S., where, under its U.S. operating company Miles Inc., it has annual sales of nearly $6.2 billion. It also shatters the results of the company's negotiations in 1986, with a payment of $25 million to Sterling Winthrop, to reestablish limited U.S. rights to the use of its name.

Bayer originally lost use of its trademark name and cross following World War I when the U.S. government confiscated Bayer's U.S. assets as alien property and sold the Bayer trademark name, Bayer cross, and aspirin business to what is now known as Sterling Winthrop, Eastman Kodak's pharmaceutical subsidiary.

District Court Judge Robert J. Ward's final injunction followed a trial concluded in July 1991 and a decision this May in which he ruled that the German chemical company had been using the Bayer name in the U.S. in violation of agreements with Sterling Winthrop. These agreements restricted Bayer's use of the name to nonconsumer, nonpharmaceutical identifications.

"The judgment really limits our freedom of action worldwide," says a Miles vice president of corporate communications, Barry S. Cohen. "We do not think the judgment is legally sound. It probably has some freedom of speech implications as well." He adds that Miles is in the process of appealing the judge's ruling. A Sterling Winthrop spokesman says that because of the appeal, his company has no comment.

In the meantime, Cohen says Miles is complying with the judge's injunction, effectively obliterating the Bayer name, by recalling and replacing any promotional items having the Bayer name that may still be in U.S. facilities. The injunction also has affected the manner in which parent Bayer A.G. recently released second-quarter earnings in Germany. Press material contained the warning that Bayer information was not for release in the U.S.

Bayer saw the handwriting on the wall a year ago in September when, in anticipation of the final injunction, it said it would jettison the Bayer USA name for its holding company and establish a new operating entity for all U.S. operations under the name of Miles. At that time, Helge H. Wehmeier, president and chief executive officer

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CHEMICAL & ENGINEERING NEWS

C&EN

SEPTEMBER 21, 1992

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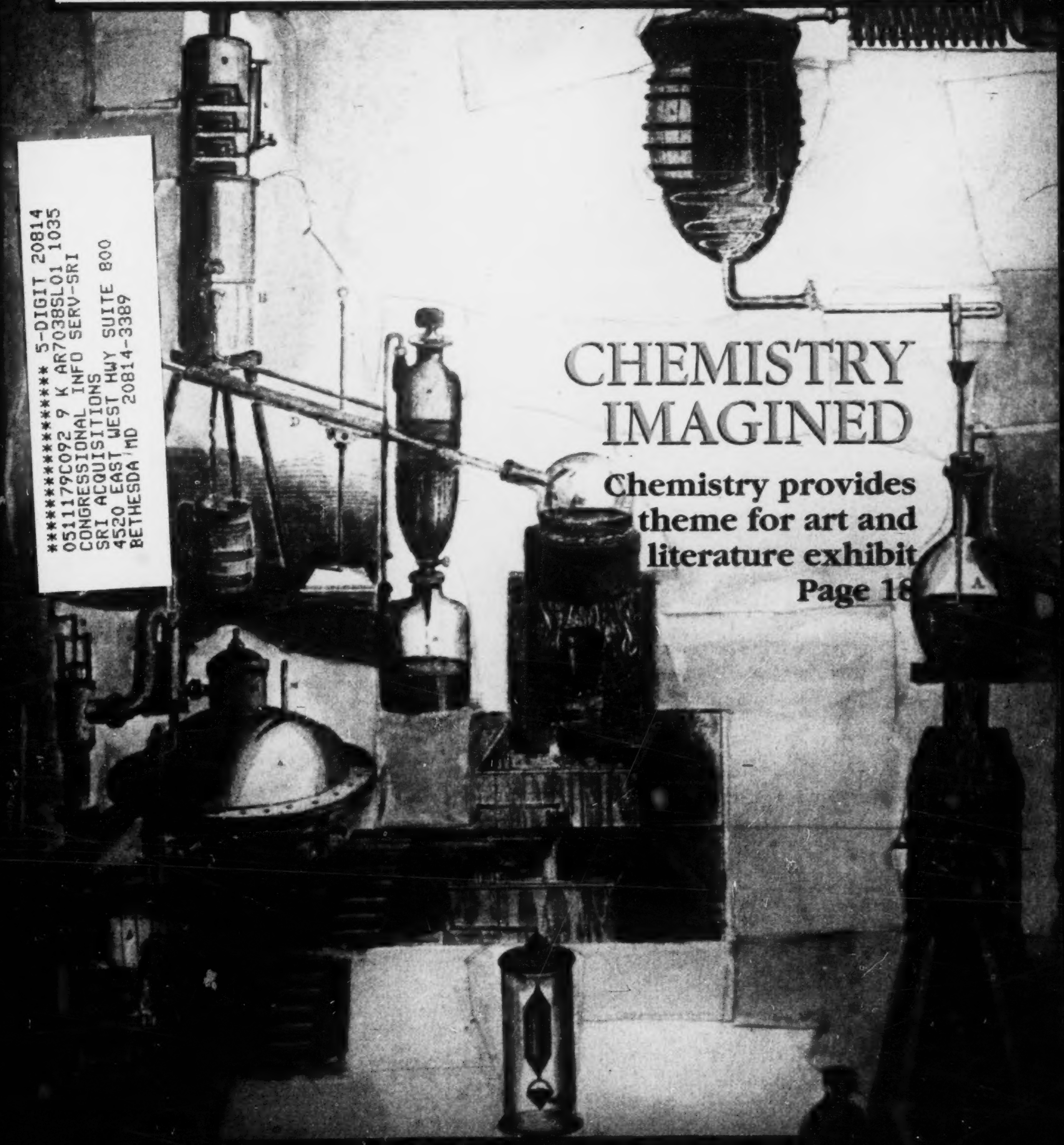

CHEMISTRY IMAGINED

Chemistry provides theme for art and literature exhibit
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CHEMICAL & ENGINEERING NEWS

C&EN

SEPTEMBER 21, 1992

NEWS OF THE WEEK

■ An extensive yearlong examination of the health of the federal government's research system has been launched by a House committee. **Page 4**

■ Advisory commission calls for major changes in U.S. patent law, including shift to first-to-file system, to conform with rest of world. **Page 5**

■ Proposal by France's Pasteur Institute that it receive the bulk of royalties on the AIDS test has been rejected by the Bush Administration. **Page 5**

■ Average human sperm counts have fallen over past 50 years, perhaps because of exposure to certain chemicals, Danish researchers conclude. **Page 5**

■ Toxicity problems have been found in a major chlorofluorocarbon substitute, but only at massive doses that aren't likely to be encountered in use. **Page 6**

COVER: Detail of collage "Steps and Processes" by Vivian Torrence. Photo courtesy of Douglas Drake Gallery, New York City

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BUSINESS

Federal regulations pose problems for most small chemical companies because such firms frequently don't have the necessary resources or the expertise on hand. **Page 9**

Sales of specialty chemicals in Western Europe are sluggish but strong growth will return, according to a study by market consulting firm Kline & Co. **Page 11**

GOVERNMENT

The Senate proves to be a bit more generous to federally funded R&D than the House, but funding increase still will be below rate of inflation. **Page 13**

Department of Defense's efforts at environmental cleanup seem to be paying off, with recent data showing a 54% reduction in hazardous waste output since 1987. **Page 15**

National Science Foundation begins series of meetings on ways to make the organization more responsive to the scientific community and to the nation's economic needs. **Page 16**

SCIENCE\TECHNOLOGY

CriSys, a software system for management training, simulates disasters and can be customized for users. **Page 21**

Research efforts for direct conversion of coal to fuel oils appear to have been redirected toward using conventional refineries for production of finished products. **Page 23**

Methods for reducing carbon dioxide emissions are appraised, as worldwide efforts to mitigate environmental effects of these emissions continue. **Page 24**

EDUCATION

Push to restructure precollege science education gets more emphasis at ACS presidential plenary session from speakers who describe ways to combat the education crisis. **Page 27**

ACS NEWS

Local sections judged to have had the best National Chemistry Week programs in 1991 receive Phoenix Awards. **Page 31**

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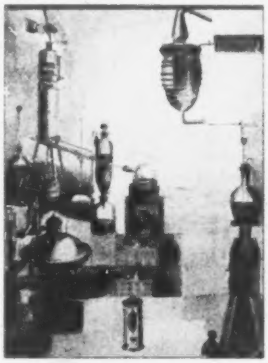

"Chemistry Imagined," a traveling exhibition in which chemistry provides the theme for art and literature, will be displayed at the National Academy of Sciences through Jan. 6, 1993. Page 18

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1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Alternatives to open-book exams

In response to Morris Feller's recommendation that examinations be "open-book" (C&EN, Aug. 17, page 5), teachers believe that examinations serve at least two, and occasionally three functions: 1. Most important—scheduled examinations induce students to study or review the course material. 2. The results of examinations provide teachers with assessments of the students' ability to utilize the course material (hence the basis for grades), and some feedback as to how well the information was presented. 3. For the earnest students, the results of examinations provide incentives for remedial study, and indicators of the relative significance of the various parts of the course, as evaluated by the instructor.

Large classes (200–400 students) force instructors to use some form of machine (or template) grading, and consequently a multiple-choice format. This is an abomination, always decried, but most teachers are convinced that this type of record keeping is unavoidable. Given practical time limitations, multiple-choice and open-book examinations are incompatible. But there are serious problems with open-book examinations, even for moderate-sized classes (25–50 students). For many students, the announcement of an open-book examination relieves the pressure to review the course material; reliance is placed on the hope of finding the proper equation, the essential concept, or sample problems in the textbook. Then, during the examination, much time is spent in leafing pages, searching for the needed material, replacing thinking with searching. Students who bring three or more books to the exam generally garner the lowest grades. The benefit of function one is minimized. Open-book examinations are recommended for advanced students who are given days to complete significant assignments, and to utilize as needed the available literature.

For moderate-sized undergraduate classes, there is a practical alternative. Suggest that students may bring to the examination all of their personal handwritten notes, as well as hand-held calculators. This has the advantage that each person must prepare notes in suitable form for rapid reference. Since the transcription of the lecture and text material is practically limited, each student must select that which he or she considers most pertinent; no one can afford to bypass the review. Reliance on rote memory of equations, definitions, and statements of general principles is thus eliminated. Clearly, the instructor must then devote more effort to devising examinations that exclude questions that require mere substitution in set formulas, and to focus on thoughtful applications. Use of the so-called ponies should be encouraged, but photocopied material should not be allowed.

S. H. Bauer
Cornell University
Ithaca, N.Y.

I agree with Morris Feller's letter regarding open-book exams, to the extent that in the real world we have available the reference books that we need.

But theoretical problem-solving ability is not the same as appropriate situational response. How often I have been grateful for the at-my-fingertips, think-on-my-feet understanding and back-of-the-envelope ability to marshall information initiated at Pomona while I was learning how to pass weekly tests given by Conway Pierce, Nelson (Nellie) Smith, and Corwin Hansch! Regurgitating facts wasn't enough: We had to know principles to understand the facts.

Currently, in presenting to our younger staff members the basic industrial hygiene (including some chemistry) needed by insurance company safety engineers, I have often been amazed at their ability to remember, and perplexed by their inability to evaluate information. It's as if all facts had the same weight and importance.

A combination of Feller's approach, and what has been successful for me, might be effective: open-book tests with so many questions of such difficulty that they could only be passed in the allotted time by students who had committed their energy to master the subject.

Richard Persoff
Senior Technical Consultant
ITT Hartford
San Francisco

Correction

- Aug. 31, page 58: Albert I. Meyers' name was misspelled.

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European specialty chemicals sales sluggish

Sales of specialty chemicals in Western Europe this year are projected to reach about $63 billion, according to an analysis by Kline & Co., the Fairfield, N.J.-based market consulting firm. This is up slightly from $62 billion in 1991 and from $58.7 billion in 1990, according to William T. Eveleth, project manager for the firm's major study, the "Kline Guide to the Western European Chemical Industry," which contains the analysis of specialties.

According to the study—which projects sales for 1992 and profitability potential for 50 specialty chemical categories—industrial coatings, agricultural chemicals, and industrial and institutional cleaning products are the largest categories of specialty chemicals, together accounting for more than one third of the total specialty sales. However, the greatest opportunities, in terms of sales growth and profitability, lie in such diverse product groups as diagnostic aids, flavors and fragrances, and water management chemicals.

The definition of a specialty chemical has always been a problem within the chemical industry, with some analysts opting for the term high value added. However, although this consideration enters into Kline's criteria, the firm defines specialties as "differentiated products sold on the basis of the functions they perform in use, as distinguished from commodities and fine chemicals, which are composition products, sold for their chemical content."

Although sales of specialty chemicals in Western Europe will grow at less than 2% in 1992 because of the recession in Europe, during the next four to five years they likely will return to more historic growth rates of 4 to 5% per year, Eveleth tells C&EN.

Of the chemicals with high potential for growth, Eveleth says, "We are projecting growth for diagnostic aids at 6% [per year] over the next five years. Advances in diagnostics technology, particularly in antibody and enzyme tests, coupled with the convenience and cost savings offered by kits, are the main driving forces for this strong growth." Diagnostic aids are likely to register 1992 sales of about $2.72 billion.

Use of flavors and fragrances, with projected 1992 sales of almost $3.67 billion, has grown strongly in past decades, according to Eveleth, and is poised for continued favorable growth. Flavors are benefiting from increased consumption of prepared foods, whereas fragrance compounds are experiencing higher demand through exports to Asia and South America, where consumption of cosmetics and toiletries is increasing. Eveleth says: "Growth in disposable income in developing nations is fueling demand for toiletries and other consumer goods. European producers of these products and their raw materials will benefit from this trend."

The other major specialty area with strong growth potential is water management chemicals, including such specialties as corrosion and scale inhibitors, flocculents, and biocides. Here demand growth will be in step with increasing environmental regulations and greater emphasis on higher value-added products and services.

William Storck

Most specialties are of average profitability, but of the others, highs outnumber lows

Category	$ Millions, 1992	Apparent profitability
Adhesives[a]	$ 1,165	High
Agricultural chemicals[b]	7,185	High
Antioxidants	465	Average
Biocides	480	Average
Catalysts[a]	1,960	Average
Chelates[c]	215	Average
Coal & fuel additives	175	High
Construction chemicals	2,150	High
Corrosion inhibitors	210	High
Cosmetic additives	1,615	Average
Defoamers	130	High
Diagnostic aids	2,720	High
Elastomers	2,390	High
Electronic chemicals	1,870	Average
Enzymes, industrial	330	Average
Flame retardants	375	Average
Flavors & fragrances	3,665	High
Food additives	2,770	Average
Foundry chemicals	335	Low
Fuel additives[d]	100	High
Industrial & institutional cleaners	5,240	High
Industrial coatings	10,120	Average
Ion-exchange resins	90	Average
Laboratory chemicals	1,070	Average
Lubricant & functional fluid additives	1,160	High
Lubricants & functional fluids (synthetic)	490	High
Metal plating & finishing chemicals[a]	$ 510	Average
Oil field chemicals[a]	375	Low
Paint additives[a]	430	Average
Paper additives	1,975	Average
Photographic chemicals	600	High
Pigments[a]	1,450	Average
Plasticizers	1,420	Average
Plastics additives	3,820	Average
Printing chemicals	215	Average
Printing inks	3,105	Average
Refinery & pipeline chemicals	175	High
Rubber processing chemicals	410	Average
Sealants & caulks	1,035	Average
Specialty polymers	3,430	Average
Specialty surfactants	945	Average
Textile specialties	725	Average
Thickeners[e]	924	Average
UV absorbers	135	Average
Water management chemicals[f]	530	High
GRAND TOTAL	$70,685	
LESS DOUBLE COUNTING	$ 7,935	
NET TOTAL	$62,750	

a Low-volume, high-priced types only. b Excludes fertilizer. c Nitriloacid types. d Excludes antiknocks and octane enhancers. e Excludes starch. f Includes specialty materials.
Source: Kline & Co

Senate Slightly More Generous than House for 1993 R&D Funding

■ ***Unlike House, Senate would fund all big science projects; most activities wouldn't even keep up with inflation***

Janice R. Long, C&EN Washington

The Senate has just about completed its work on the appropriations bills that will fund the government civilian research and development activities in fiscal 1993, which begins Oct. 1. The full Senate has made no major changes, and very few minor ones, in the levels of support recommended by the Appropriations Committee. It has agreed to fund all of the so-called big science projects. Overall, it has provided slightly more money for R&D activities than did the House, but not enough more to allow the majority of those activities even to keep up with the current low rate of inflation.

Agencies that last year were looking at budget increases of anywhere from 6 to 27% will have to learn to live with much smaller increases in fiscal 1993. For example, the National Institutes of Health (NIH) saw its overall budget rise 10% to $8.1 billion in fiscal 1992. The Senate Appropriations Committee has allowed an increase of just 3% to $8.4 billion for the coming fiscal year, the same percentage increase set by the House. This is the first time in years that both branches of Congress haven't upped an Administration's budget request. The Administration was seeking a 5% increase for NIH for fiscal 1993.

Missing from the NIH appropriations bill this year are any references to abuses, such as charging unallowed expenditures under the independent cost recovery system for research grants, which so exercised the Appropriations Committee last year. Also missing are provisions prohibiting the agency from spending some of its funds until the last day of the fiscal year. This year, NIH had been told to hold back 6% of its budget, or $563 million, for expenditure on Sept. 30, which means the money won't actually be distributed until fiscal 1993. And the Administration has asked that spending of $619 million worth of NIH's fiscal 1993 budget be similarly delayed.

However, the House Appropriations Committee refused to go along. It called the request a "practice, which was started by the Administration in its 1992 budget request, an accounting gimmick that has the effect of making future budget decisions even more difficult than they already are under the spending caps agreed to in the Budget Enforcement Act of 1990." The Senate committee followed suit.

The Senate also approved a 3% increase in funding to $5.0 billion for the Department of Energy's energy R&D programs. That's good news in comparison to the House's decision to cut overall funding for those same programs 8% to $4.5 billion. And the Senate reversed the House's decision to kill the Superconducting Super Collider.

However, the good news doesn't apply to basic energy sciences, which includes DOE's research programs in the chemical and materials sciences. Whereas the House froze funding for those programs at current levels, the Senate provided an increase of only 1% to $775 million. Under the Senate bill, funding for DOE weapons R&D activities would rise 6% to $1.5 billion, compared with the House's action that froze funding at $1.4 billion.

Compared with NIH and DOE, the National Science Foundation (NSF) looks like a winner in the 1993 budget cycle. The House allowed it a 4% increase to $2.5 billion and the Senate a 7% increase to $2.6 billion. But most of the Senate increase is slated for education and human resources as well as instrumentation and facilities, plus a new $55 million defense conversion traineeships program. This program, according to the committee report, will provide a stipend and cost-of-education allowance to academic institutions capable of providing effective programs that will aid the estimated 127,000 defense engineers who may lose their jobs during the next few years as they make the transition to work in the civilian R&D enterprise.

Monies for NSF's research and related activities account were essentially frozen by the House at the current funding level of $1.9 billion, but under the Senate bill they actually decrease by $13 million. The House Appropriations Committee said that "in view of the very difficult domestic discretionary budget climate, which is reflected in this recommendation, [we are] concerned that large science facility projects will increasingly erode funding for individual investigator grants. Therefore, the committee directs the foundation and the National Science Board [NSB] to reconsider the priority, structure, and funding options relative to the Laser Interferometer Gravitational Wave Observatory; the eight-meter (GEMINI) telescope project; a research aircraft for the National Center for Atmospheric Research (NCAR); and a new Arctic research vessel." The committee directed NSF not to fund the projects until the NSB review is completed.

The Senate Appropriations Committee took a different tack—eliminating funding for NCAR's aircraft and scaling back funding for the other projects. And the committee will not require that the NSB report be completed before funding. However, the Senate report on NSF's appropriations bill is awash in directives to the foundation that tell it in minute detail how and where it should spend its funds, and redirect its activities, and requiring re-

Senate gives big boost to national standards institute

$ Millions	1993				% difference	% change
	Senate appropriations	House appropriations	Administration request	1992	Senate/House	1992–93 (Senate)
Health & Human Services	$ 9,953.6[a]	$10,057.4	$10,219.4	$ 9,483.3	–1%	2%
National Institutes	8,365.3	8,354.9	9,794.9	8,101.2	0	3
Cancer	2,010.4	1,998.6	2,010.4	1,951.5	1	3
Heart, Lung & Blood	1,228.4	1,228.4	1,245.4	1,191.5	0	3
Allergy & Infectious Diseases	989.1	990.1	1,010.8	960.9	0	3
General Medical Sciences	833.0	842.2	862.1	815.1	–1	2
Diabetes, Digestive & Kidney Diseases	688.6	688.6	699.8	662.7	0	4
Neurological Disorders & Stroke	607.1	605.1	615.2	581.8	0	4
Child Health & Human Development	534.1	534.1	545.2	519.7	0	3
Aging	405.2	402.2	407.3	383.6	1	6
Eye	279.1	279.1	285.1	270.3	0	3
Environmental Health Sciences	255.1	255.1	261.5	252.0	0	1
Arthritis & Musculoskeletal & Skin Diseases	214.6	214.6	214.9	203.9	0	1
Dental Research	163.3	163.3	166.7	159.1	0	3
Deafness & Other Communication Disorders	157.3	153.5	157.3	149.1	2	6
Alcohol, Drug Abuse & Mental Health Administration	1,165.5	1,280.9	1,309.1	1,274.2	–9	–9
National Center for Research Resources	315.6	314.4	318.2	314.6	0	0
National Center for Human Genome Research	107.2	107.2	110.4	104.9	0	2
NASA R&D	7,117.1	6,670.7	7,731.4	6,409.7	7	11
Space station[b]	2,100.0	1,750.0	2,238.9	1,986.8	20	6
Energy	6,529.6	5,932.5	6,632.6	6,307.9	10	4
Energy R&D	5,008.5	4,500.9	5,168.4	4,875.3	11	3
General science & research	1,460.8	998.9	1,652.7	1,472.5	46	–1
Superconducting Super Collider[b]	550.0	33.7	650.0	483.7	153	14
Basic energy sciences	774.9	764.9	813.9	764.7	1	1
Environmental restoration & waste management	709.7	709.7	707.0	602.5	0	18
Fossil	422.7	412.6	311.3	452.3	2	–7
Environmental R&D	363.7	356.7	384.7	353.3	2	3
Fusion	335.0	339.7	359.7	337.1	–3	–1
Nuclear	296.5	304.3	310.3	336.7	–3	–12
Conservation	318.0	311.4	326.1	260.0	2	22
Solar, other renewables	271.5	247.0	247.0	241.7	10	12
University & science education programs	55.7	55.7	55.7	54.5	0	2
Weapons R&D	1,521.1	1,431.6	1,464.2	1,432.6	6	6
NSF	2,618.0	2,541.0	2,888.0	2,449.0	3	7
Research & related activities	1,859.0	1,879.0	2,211.5	1,872.0	–1	–1
Education & human resources	510.0	465.0	479.5	465.0	10	10
Antarctic program	143.0	163.0	163.0	78.0	–12	83
Defense conversion engineering traineeships	55.0	0	0	0	100	100
Instrumentation & facilities	50.0	33.0	33.0	33.0	51	51
Critical Technologies Institute	1.0	1.0	1.0	1.0	0	0
USDA	1,330.8	1,328.1	1,300.1	1,396.7	0	–6
Agricultural Research Service	684.1	695.4	714.0	711.5	–2	–4
Cooperative State Research Service	468.0	446.0	416.0	504.7	5	–7
Forest research	178.7	186.7	170.1	180.5	–4	–1
Commerce	794.2	447.1	504.4	459.7	78	73
National Institute of Standards & Technology	597.0	250.9	310.7	246.7	138	142
Oceanic & atmospheric research	197.2	196.2	193.7	213.0	1	–7
EPA extramural R&D	323.0	338.5	338.5	320.9	–5	–1
TOTAL	$28,666.3	$27,315.3	$29,614.4	$27,138.8	5%	6%

Note: All numbers are estimated. a Amounts recommended by Senate Appropriations Committee. b Funds included in total.

ports to Congress on a wide array of subjects. Many of these directives seem to be aimed at increasing NSF's ties with industry and focusing its activities on "technologies deemed to be critical to the nation's competitiveness."

That emphasis on competitiveness is behind the astonishing 142% Senate-approved increase to $597 million in funding for the National Institute of Standards & Technology (NIST). The House held NIST to a much more modest 2% increase to $251 million. Behind the surge in funding is a new account that the Senate added to the NIST budget—defense economic conversion, research, and technology—and funded at $109 million. According to the Appropriations Committee report, the "initiative is intended to capitalize on the agency's experience and charter to stimulate technological innovation by facilitating the conversions and transition of American industry to nondefense manufacturing." The vast majority of the funds—$100 million—are to be used in NIST's external grant programs: the advanced technology program, manufacturing technology centers, and the state technology extension programs.

The Senate also provided $202 million for NIST's central scientific and technical research and services programs, an increase of 10% over current levels. That includes an increase of $700,000 for chemical science and technology. Funding for NIST's industry technology services is up 35% to $86.1 million.

Funding for the Environmental Protection Agency's extramural R&D programs would decline 1% to $323 million under the Senate appropriations bill, but would rise 5% to $338.5 million under the House bill. But that's not the only difference between the two bills. The Senate Appropriations Committee deleted from that account $19 million earmarked by the House for 16 research projects, but added back $9.5 million for nine of its own priority projects.

Final budget numbers for all of these programs must still be ironed out in House-Senate conferences, and it may turn out that the Senate's new defense conversion program won't emerge unscathed. In fact, it may disappear entirely. However, funding for most research programs probably will come in somewhere between the House and Senate figures. ☐

CHEMICAL & ENGINEERING NEWS

C&EN

SEPTEMBER 28, 1992

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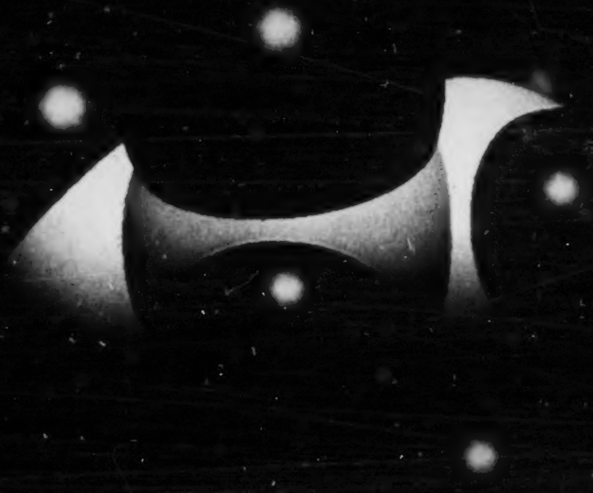

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CHEMICAL & ENGINEERING NEWS
C&EN
SEPTEMBER 28, 1992

NEWS OF THE WEEK

- Taking an unprecedented step in continuing battle over "pork-barrel science," House votes to deny funding earmarked for 10 academic research facilities in an appropriation bill. **Page 6**
- Biochemist Bruce M. Alberts has been nominated to be the next president of the National Academy of Sciences. **Page 7**
- Currency turmoil sweeping Europe may have overall positive effects for the European chemical industry. **Page 7**
- Technology and future innovations are the emphasis of a science competition for precollege students that was launched last week by the National Science Teachers Association and Japan's Toshiba Corp. **Page 8**
- Publishers Elsevier and Reed International have agreed to merge next Jan. 1, forming one of the world's largest scientific publishing companies. **Page 8**

COVER: Drawings of two enantiomers, D- and L-glyceraldehyde, by Tripos Associates, St. Louis, using molecular modeling program Sybyl

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1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600, TDD (202) 872-4432
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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189, outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
(For list of offices see page 109)

Office of Ombudsman: (800) ACS-5558, No. 8-5

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Canadian GST Reg. No. R127571347

LETTERS

Future job market in chemistry

I recently attended the meeting of the Committee on Professional Relations at the 204th American Chemical Society national meeting. The picture presented by the participants ranged from abject gloom to euphoria regarding the future job market. In contrast, the mood of the audience was extremely negative.

The major controversy among the speakers was the proper prediction of numbers of people in chemical employment in the 21st century. Optimistic values for the job market were based on a growth in the economy, the requirement for more teachers for the greater number of students taking high school and college chemistry (based on the projected need for scientific literacy in the workplace), and no dimunition in research funded by the government and the defense industries. Pessimistic numbers were founded on major sections of research moving overseas, greater efficiency in the research community, lower R&D support from the government, and negligible growth in the economy. Although some speakers indicated a turnaround in the current depressed job market as early as 1996, others forecasted that the change would not occur until 2005. However, all the speakers stressed that future supply-and-demand numbers were subject to major modification depending on unforeseen circumstances.

On one subject there was general agreement: Chemists are currently hurting in the job market. Terminations at major companies have essentially ended the careers of chemists in their mid-40s to early 60s with very little chance of reentry into the marketplace in either 1996 or 2005 as their skills diminish with lack of use. Decreased hiring rates in a depressed market have lowered the expectations of recent graduates and have driven them either into postdoctoral positions or into fields that require minimal chemical training. If a shortage does occur in the future, it will not be based on increased demand, but rather on a mass exodus of highly trained individuals from the chemical field who are not currently employable.

What is the responsibility of the chemical industry in the current crisis in employment? Certainly it is not to berate the colleges for not training for a specific specialization desired by the company while the same corporation simultaneously is terminating hundreds of other chemists. Rather the chemical industry, up to a certain point, has an obligation to maintain a viable, balanced research staff for future growth. To accomplish this objective, ACS must open two-way communication with the major industrial chemical companies that emphasizes the long-term destructive consequences of their short-term hiring practices.

The pain is real; the chemical profession has been reduced to a slave market for too many well-educated scientists. It is time that the rosy predictions for the future be replaced by a realistic examination of the present plight in chemical professional employment. ACS, the chemical industry, and the colleges should alert budding scientists to the degree of opportunity in the field of chemistry to reduce future disillusionment.

Nelson Marans
Silver Spring, Md.

Behavior modification

I am prompted to write this letter by a comment from one of the society's student affiliates who presented a poster paper at the San Francisco meeting. The student noted that a number of university faculty members stopped by his poster, but upon finding that he was not interested in attending their graduate program, immediately moved on to other posters. This seemed to be a fairly common occurrence at the student affiliate session. This kind of boorish behavior has no place at a student affiliate session, or, for that matter, at any session.

Undergraduates who have spent the time, effort, and money to come to a meeting represent the very best of our potential new colleagues and they deserve the same kind of personal respect as any other researcher. Not only is the behavior rude, it is also pointless. Seniors who plan to go to graduate school usually have made their decisions before the

Correction

- Sept. 21, page 6: CFC-12 is CCl_2F_2, not CH_2F_2.

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Asian chemical growth poses challenge to Western chemical firms

Earl V. Anderson,
C&EN Northeast News Bureau

Sir Denys H. Henderson, chairman of the U.K.'s ICI, notes that Columbus was actually looking for "the Orient" when he bumped into America. Today, the world's chemical industries are discovering what Columbus missed.

If there were any lingering doubts that Asia is where the action is for the chemical industry, they were thoroughly squashed at the 2nd World Chemical Congress, held recently at Newport Beach, Calif. The pattern of world chemical demand likely will change significantly during the next 10 years, and Asia will be the trigger for that change.

Henderson came to the Chemical Congress from London, but he talked only about Asia. Edward Delboy, vice president of Shell International Chemical, also came from London. He, too, emphasized Asia. Masaki Yoshida, president and chief executive officer of Mitsubishi Petrochemical, flew in from Japan. And he stressed the chemical phenomenon that is Asia.

Asia, says Henderson, will influence significantly a large part of the industry's strategic planning and business decisions. Three distinct trading blocs are emerging in the world—North America (including Mexico), an expanding Western Europe, and the Asia-Pacific region. And if any one of those three blocs is leading the way toward a different world order, it is Asia, he says.

And with good reason. Last year, the region accounted for 21% of the world's gross domestic product (GDP), up from only 13% in 1974. With the economies of Asia growing at more than twice the rate of either the U.S. or Western Europe, by the year 2000 that share will jump to 24%, says Henderson.

Henderson's growth figures exclude the former communist countries. But Mitsubishi Petrochemical's Yoshida says the three countries of Indochina—Laos, Cambodia, and Vietnam—have tremendous growth potential. Vietnam, in particular, merits special attention.

However it's measured, economic growth in Asia will be robust and will have an impact on the world chemical scene. Demand for chemicals in Asia is growing twice as fast as in the West. With only 18% of world chemical sales in 1974, Asia has boosted its share to 26% in 1990 and likely will push it up to a hefty 30% by 2000. This rapid growth has been—and will be—based on a strong buildup of the region's industrial foundation and not on agriculture, which accounts for less than 10% of GDP.

These economic tidbits indicate that Asia poses a much bigger challenge for Western companies than these firms realize, says Henderson. Chemical companies are no exception.

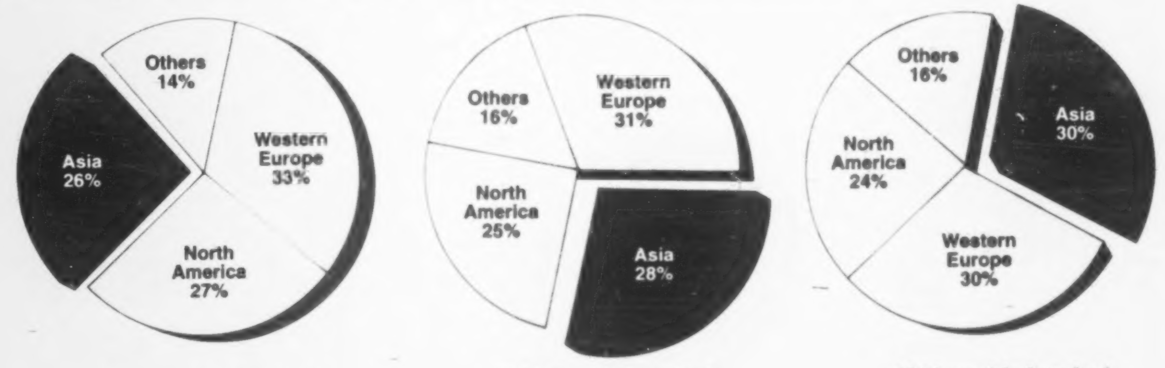
Asia currently is a net importer of chemicals. But by the end of the decade, Henderson expects it will be a net exporter. As a result, he believes Asia poses a clear threat to the chemical industries in North America and Western Europe.

The threat is twofold. Asian chemical companies first will try to satisfy new markets in their own region. This will make it much more difficult for Western chemical companies to maintain current export levels to the region. It also will make it more difficult for them to find ways of participating fully in the region's future growth. To make matters worse, Henderson says Asian chemical companies also likely will try to establish strong chemical export markets for themselves in the West.

These trends are bound to have an impact on Japanese chemical companies, says Yoshida. Japanese chemical exports, which until now have helped satisfy demand throughout Asia, will be replaced by local production. When that happens, Yoshida says Japanese chemical companies, instead of maintaining current export levels for their products, will be exporting technology, capital, and management expertise to their Asian neighbors.

Shell International's Delboy agrees that Japanese chemical firms will be active in the Asia region, as far as ethylene and its derivatives are concerned. And he agrees that they will, indeed, be providing money, technology, and

Asia is expected to account for increasing share of world chemical market



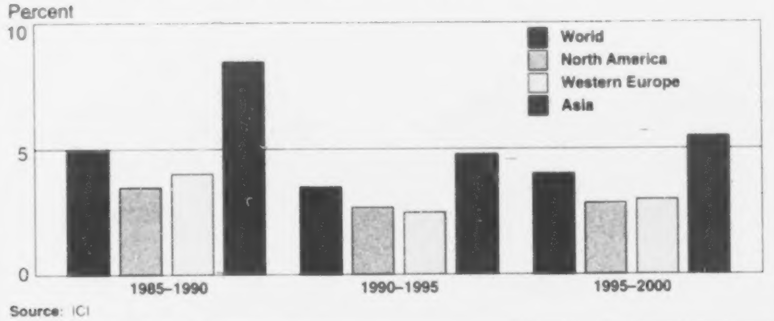
1990 world chemical market = $1.08 trillion[a]

1995 world chemical market = $1.28 trillion[a]

2000 world chemical market = $1.55 trillion[a]

Note: Percentages are rounded to nearest whole number. **a** At 1990 prices and exchange rates. **Source:** ICI

Chemical demand growing fastest in Asia



Source: ICI

management expertise as they globalize their activities.

Japan's big commodity trading houses will also be involved. For them, says Delboy, even minor equity investments could help secure plant and equipment contracts, feedstock supplies, and market access for their other products.

But there also will be room for other international investors—large U.S. and European firms—in the Asian ethylene picture, says Delboy. Faced with mature home markets and diminishing exports, these large Western chemical companies probably will invest overseas to maintain growth. Asia will be, or at least should be, a prime target.

International oil companies have what it takes to participate in a growing Asian petrochemical industry, says Delboy. They are experienced in investing and operating in diverse geographical areas. And 10 of the 15 largest international petrochemical companies are affiliates of oil companies.

Because they are already operating in many Asian countries, the oil companies know the region well. Local authorities also know them, which makes the oil giants attractive partners for local investors.

But there should be room for much more foreign investment in Asian ethylene projects. Delboy believes that up to 12 million metric tons of new ethylene capacity will be needed in Asia between 1990 and 2000. Depending on size and location, that huge volume means between 25 and 30 new ethylene crackers. To put that in context, the additional capacity needed in Asia represents about two thirds of Western Europe's current capacity.

Delboy estimates that a new olefins complex, including derivatives plants, costs upward of $1.5 billion at today's prices. "There would seem to be plenty of action to be had in the region," he says.

Delboy also estimates that about 40% of this new action—such as new crackers in Japan, South Korea, and some in China—will be taken by domestic players. But that still leaves about 60%, or about 7 million metric tons per year, of ethylene capacity that could be developed with major foreign involvement.

One company, at least, that isn't interested in Asian petrochemical plants is ICI. "You won't see any ICI petrochemical plants in Southeast Asia," Henderson says, "at least not while I'm chairman."

Nevertheless, some Western companies will want to participate in meeting the huge ethylene demand that is certain to materialize in Asia. Last year, according to Delboy, ethylene demand in the region was about 13 million metric tons. He believes it could reach 24 million metric tons by 2000. That would amount to a tidy 29% of global demand by then.

Asia now is a major ethylene importer, bringing in more than 3 million metric tons in 1990. Most of this came in as ethylene derivatives, largely from the Middle East and the U.S.

This import deficit, along with the growth in internal demand, provides the stimulus for increasing local output. Western petrochemical companies that fail to participate will pay the penalty, says Delboy.

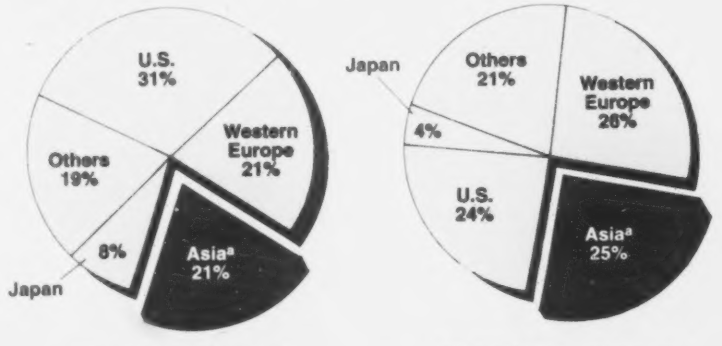
There's no doubt that world chemical demand patterns will change drastically during the next 10 years, not only for ethylene, but for many other chemicals as well. The one-word reason: Asia.

For instance, chemical demand in Asia is expected to grow an average [illegible]% per year between 1990 and 1995, greater than the expected 3.4% world average and much greater than the anticipated 2.7% and 2.5% for North America and Western Europe. And Asia's average annual 5.5% growth rate in chemical demand between 1995 and 2000 also is likely to be the world's fastest.

What does this mean in dollar terms? According to Henderson, it means that by 2000, Asia's chemical market will hit $460 billion (in 1990 prices and exchange rates). It also means that, by 2000—less than eight years away—Asia's chemical market will probably be larger than North America's ($380 billion) and almost as large as all of Western Europe's ($465 billion).

But achieving that success won't be easy for Asia's burgeoning chemical industry. Henderson points out that, right now, the industry is relatively fragmented, at least by the standards of the major Western chemical companies. Although

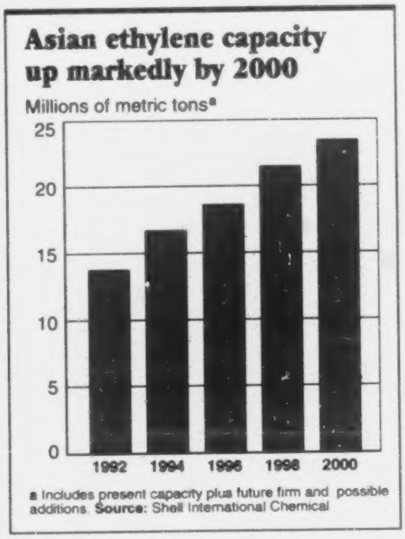
Asia likely to take 25% of global ethylene output by 2000



1990 ethylene demand = 58.6 million metric tons

2000 ethylene demand = 85.8 million metric tons

[a] Asian countries other than Japan. **Source:** Shell International Chemical



Asian ethylene capacity up markedly by 2000

[a] Includes present capacity plus future firm and possible additions. **Source:** Shell International Chemical

chemical demand in Asia may be enormous, many of the individual Asian chemical companies are too small and their markets too localized for them to support the level of research spending that is needed to become a global force. However, with rapidly growing chemical demand right at their doorsteps, most Asian chemical companies have powerful growth ambitions, says Henderson.

Those ambitions could be realized by reorganizing and joining forces, adds Henderson. He points to recent talks between Japan's Mitsui Toatsu and Mitsubishi Petrochemicals as an example. So far, he says, "firm proposals are not evident, to Western eyes at least."

Henderson is right on target. Mitsubishi Petrochemical's Yoshida says that reorganizing is absolutely necessary for Japan's petrochemicals industry if it expects to remain internationally competitive. And he rates as "probable" a large-scale change by 2000.

Japan's ethylene situation provides a good example of why such a change is, indeed, probable. There are 12 Japanese ethylene producers competing for a domestic market of only about 6 million metric tons. This has put a lot of pressure on prices—and profits. In addition, says Yoshida, research and development efforts often overlap and are redundant.

This time, however, reorganizing Japan's petrochemical industry may be different than past efforts, says Yoshida. In the past, Japan's powerful Ministry of International Trade & Finance called most of the shots. This time, says Yoshida, reorganization likely will be left to the individual companies.

Some change has already begun among Japanese chemical companies. One example: Mitsubishi Petrochemical and Mitsubishi Kasai have co-invested in a new 300,000-metric-ton-per-year ethylene plant at Kashima. Completed in June, the plant may be expanded later to 450,000 metric tons.

But it will be China, as well as Japan, that will play a key role in shaping Asia's chemical future and Western chemical companies' response to it. Japan, South Korea, and Hong Kong are investing heavily in China's chemical industry. Recently, China relaxed its import controls and is trading more freely. And because its vast agricultural sector is still relatively primitive, there are great opportunities for agrochemicals.

China's textile industry is growing rapidly and the Japanese already are exporting large amounts of dyes to China to satisfy its requirements. So, too, are South Korea and Taiwan. China's relationship with Taiwan has already become more "pragmatic," says Henderson. And during the next 10 years, both Hong Kong and Taiwan are expected to play a crucial role in China's emergence as a world superpower.

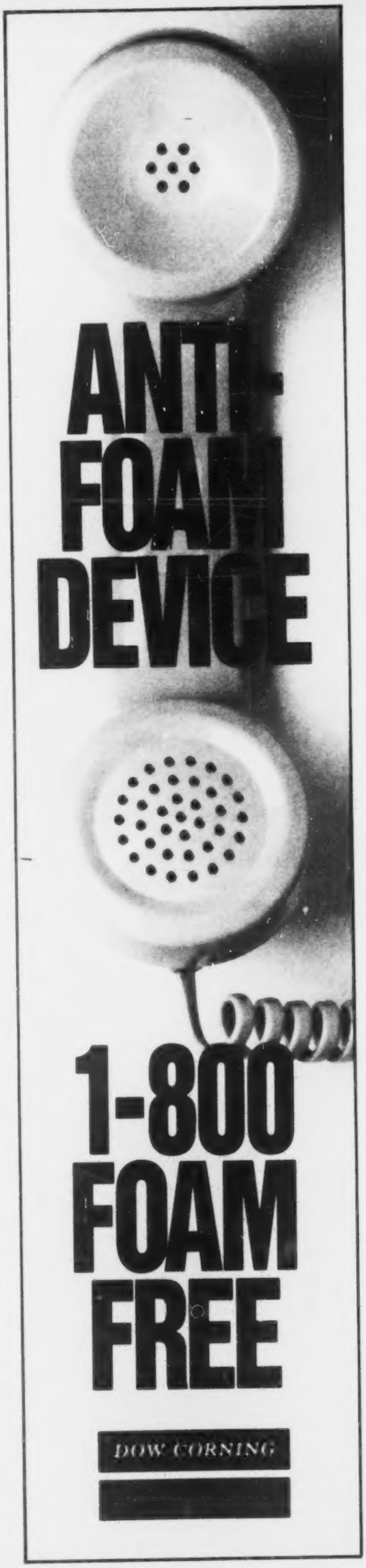
"Overall, I see danger in a restructured and increasingly powerful [Asian] chemical industry being able to consolidate its position in China and the rest of the region," says Henderson. Danger, that is, unless Western chemical companies are fast on their feet.

"You have to be there," says Henderson, referring to China. Recently, ICI has been slowly but steadily putting money into the country.

In addition, Asia's expanding chemical companies will want to invest overseas to broaden their technological base and to increase their share of world chemical trade. Japan, of course, already is doing just that.

In fact, Henderson sees Japan remaining the principal challenge to Western chemical dominance during the next 10 years. Its overseas investment will continue to increase. And, outside their own country, Japanese companies will focus on the high-value-added, high-technology end of the business—primarily pharmaceuticals and biotechnology.

Henderson says what has already been seen in the automotive and electronics industries may well happen in chemicals. Japanese chemical companies, with their products already approved to Japanese standards, will follow wherev-



CIRCLE 20 ON READER SERVICE CARD

er their important customers—the major consumer-oriented Japanese companies—have blazed a trail. Japanese chemical companies are small by Western standards. But they have proven their reliability to their major customers. Thus, says Henderson, it is only natural—and safe—for them to follow their customers wherever they go.

And their customers may, indeed, continue going elsewhere, even more so than they have been ever since the Plaza Accord of 1985—in which nations agreed to coordinate interest and exchange rates—sharply increased the value of the yen and put pressure on Japanese exports.

Yoshida says Japan's domestic "assembly industries" have almost reached their physical limits. As a result, he expects domestic chemical demand in Japan to reach a saturation point as the year 2000 approaches.

So what can Western chemical companies do about what Henderson calls "the challenge of Asia-Pacific?" Based on ICI's 40 years of experience in Japan, he says it is possible for Western companies to overcome the difficulties, to work with Japanese partners, and to benefit from their expertise.

But ICI also has learned that it "can go it alone," says Henderson, not only in the Japanese market, but in other Asian countries such as Taiwan and Malaysia as well. Customers in these countries, he adds, are anxious to get the leading-edge technology and innovative capability of Western chemical companies.

The Asian chemical industry is destined to continue expanding rapidly, regardless of what Western companies may try to do to prevent it, says Henderson. To him, there are two choices: Western chemical companies can either forge alliances with emerging local producers, or they can lose patience and try to erect political and trade barriers that would shut off Western markets to the Asians. "I would suggest that we are too late for the [latter]," he says.

He points out that John Jay, an early U.S. Secretary of State, referred to the Pacific as "the ocean of the future." Henderson is convinced that future is here. ☐

Environment likely to be factor in trade talks

As more and more countries negotiate international trade agreements, environmental concerns will inevitably become even more closely linked with the customary economic issues. This has been apparent in the stalled Uruguay round of multilateral trade talks. It has become even more obvious in the North American Free Trade Agreement (NAFTA) that Canada, Mexico, and the U.S. recently negotiated.

Loud protests from environmental groups and some politicians notwithstanding, John A. Krol, vice chairman of Du Pont, says that, environmentally, NAFTA "will be a plus from the word go." NAFTA's "green language" is "precedent-setting," he told the recent 2nd World Chemical Congress held in Newport Beach, Calif. And it is the first trade agreement to include sustainable development as a specific objective. To Krol, sustainable development is what the future is all about.

The philosophy of sustainable development recognizes that environmental regulations and the way they are enforced vary from country to country. This is understandable, says Krol. Poverty-stricken countries and those with populations facing starvation have different priorities than wealthy nations. In poor countries, global environmental considerations are likely to get short shrift.

But sustainable development is a concept that seeks to balance environmental and economic issues, he says. The Business Council for Sustainable Development, of which Du Pont and other chemical companies are members, is working to develop this concept into an industrial philosophy.

The basic concept is simple—companies, including chemical companies, must manage their businesses in a way that fulfills the needs and aspirations of a growing world population without compromising the ability of future generations to meet their own needs. It starts, says Krol, from the position that economic and industrial development is essential if people in developing countries are to rise out of poverty. But the second article of faith, as Krol calls it, is that this can be done without destroying the environment on which economic growth ultimately depends.

Because sustainable development is built into NAFTA, Krol believes it can serve as a model for future international trade agreements—in the Western Hemisphere and elsewhere. NAFTA and similar trade agreements, he says, will improve environmental quality. Just as important, environmental standards will become more comparable among the nations involved. And, contrary to many protesters, he believes NAFTA will "level up" Mexican environmental standards to U.S. levels rather than "level down" U.S. standards to present Mexican levels.

There are two reasons for this, says Krol. First, liberalizing trade and markets likely would improve living standards in poorer countries and raise their awareness of environmental problems. And second, more directly, trade agreements increasingly address a range of political issues, including environmental concerns. The European Community's EC-92 initiative is a case in point.

So, too, is NAFTA. According to Krol, it reflects the growing relationship between trade and environmental issues. One significant sign: Representatives from the environmental community are on official trade advisory committees.

Krol believes the freer trade and investment that NAFTA provides will stimulate the flow of private-sector financial, technological, and managerial resources toward solving environmental problems. It is because of this, together with efforts to harmonize environmental regulations throughout North America, that environmental quality will level up, not down.

There is evidence this already is happening, he says. A Business Roundtable survey shows U.S. companies not only comply with Mexican environmental laws, but that many also volun-

Krol: sustainable development is the future

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3-Nitro-o-toluic acid
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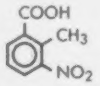
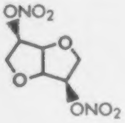
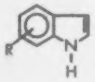


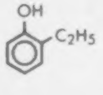
ISDN
Isosorbide dinitrate,
mixtures with lactose, etc., UPS



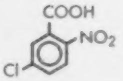
substituted
Indoles
R = CH3, OCH3, COOCH3, Cl, etc.



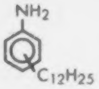
2-Ethylphenol



5-Chloro-2-nitrobenzoic acid



Dodecylaniline
(isomer mixture)



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Petrochemical capacity rises in Middle East

The traditional petrochemical industries in the U.S., Japan, and Western Europe are going through some rough times, ones that likely will continue to be tough throughout the remainder of the 1990s. And petrochemical plans unfolding in the Middle East won't make things any easier for them.

Countries in the Middle East already have plenty of petrochemical capacity. Nevertheless, they are expanding capacity now and new plants are "waiting in the wings," says Abdullah S. Nojaidi. New output from these plants probably will start hitting world markets during the mid-1990s. That's just when Nojaidi, president of Saudi Arabia's SABIC (Saudi Basic Industries Corp.) Marketing Ltd., expects world petrochemical markets to improve.

Nojaidi told the recent 2nd World Chemical Congress in Newport Beach, Calif., that, "at a minimum," Middle East ethylene and derivatives capacity will double during the decade. Ethylene capacity alone will rise from 3.15 million metric tons in 1990 to almost 4 million metric tons in 1995, then jump to 6.3 million metric tons by the year 2000. By then, the Middle East will account for 6.5% of the world's ethylene capacity, up from 4.9% two years ago.

Coupled with similar expansions in Asia and Latin America, this spells trouble for the petrochemical industries in what Nojaidi calls the triad—the U.S., Japan, and Western Europe. In the 1990s, he expects world ethylene capacity to increase 50%. However, triad capacity will rise by less than a third, although capacity in the rest of the world will double. The triad's share of world ethylene capacity will fall from 66% to 55% during the decade.

Although he sees the world petrochemical picture improving later in the decade, the short-term petrochemical picture is less sanguine. By 1995, world ethylene capacity will increase by one third; demand will rise by less than half that amount. As a result, world petrochemical operating rates will drop from an average 91% in 1990 to only 79% in 1995. "This has to be a worrisome matter for all petrochemical producers," says Nojaidi.

From his vantage point in the Middle East, Nojaidi sees "difficult times" for the world petrochemical industry. Today's prices do not justify investing in the new capacity that will be needed to satisfy market demand by the end of the decade. In the short term, demand is falling, costs are rising, selling prices are low, and the recession—and overcapacity—lingers.

So why the many expansions in the Middle East? Nojaidi contends that long-term petrochemical prospects warrant "timely" capacity additions. The key word, he says, is timely. Most of the new Middle East output will enter world markets late in the decade. By then, says Nojaidi, although market growth rates may still be low, they will be working off a higher base and will be able to absorb the new capacity.

He also believes profits, not volume, will be the key to petrochemical prosperity. This makes him wonder if the old, small, inefficient plants with little or no stake in feedstocks (read Europe) can survive in the more demanding and competitive climate that is coming.

"The Middle East," says Nojaidi, "has paid for its ticket to the party." It certainly has the feedstock. And it has invested heavily in massive feedstock gathering systems, infrastructure networks, and a host of world-scale petrochemical plants.

He believes if a region has the feedstocks, the financial capability, and the nerve to plunge into previously uncharted

Middle East will expand ethylene capacity

Country	Ethylene capacity (thousands of metric tons per year) 1990	1995	2000
Iran	10	735	735
Iraq	150	0	600
Kuwait	0	0	300
Qatar	280	280	600
Saudi Arabia	2,250	2,500	3,000
Turkey	460	460	775
U.A.E.[a]			300
TOTAL	**3,150**	**3,975**	**6,310**
World capacity	64,000	85,000	97,000
Middle East as % of world	4.9%	4.7%	6.5%

[a] United Arab Emirates **Source:** SABIC Marketing

waters, then it should press its economic advantage. If the Middle East needed any incentive to diversify away from relying on oil revenues alone, it was the European Community's move toward a $10 per barrel energy tax on oil.

In Iran, the petrochemical complex that was destroyed in the Iran-Iraq War is being rebuilt. Other plants are under construction. Oman is in the "advanced planning" stage for an offshore, barge-mounted methanol plant. Kuwait, a major fertilizer producer, is planning an ethane cracker and derivatives complex.

Bahrain has a methanol-ammonia complex, has looked at the possibility of a polypropylene plant, and now is considering an aromatics and derivatives complex as well as a urea plant plus a plant to produce methyl *tert*-butyl ether. And Qatar has in the works a liquefied natural gas complex to serve Asian markets. It also plans to build a new ethane cracker and derivatives complex. The United Arab Emirates may well build an ethane cracker and polyethylene complex.

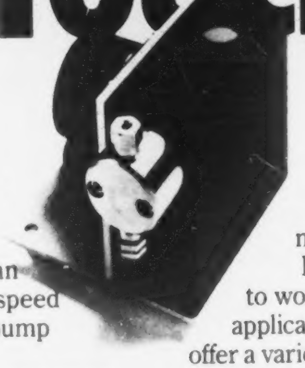
But Saudi Arabia is, and will remain, the petrochemical champion of the Middle East. The 16-year-old SABIC supplies more than 10 million metric tons per year of petrochemicals to more than 70 countries. Under its current investment strategy, says Nojaidi, SABIC hopes to capture a 4 to 5% share of world chemical markets. Current investment schedules will enable the company to increase its petrochemical capacity from 12 million metric tons annually to 17 million metric tons "in coming years." The goal for later in the decade—20 million metric tons annually.

SABIC is building its fourth ethylene cracker. It will be a variable-feed unit that will enable the company to enter the propylene, butadiene, and aromatics chains of products. Notably, SABIC will produce 200,000 metric tons per year of polypropylene. It also will produce 2-ethyl hexanol and benzene to meet demand at its expanded styrene plant.

The company also is moving up the product chain to produce polyester for fibers and plastic bottles. If all of its expansion plans are completed, SABIC's capacity for its many petrochemical products will be awesome.

Meanwhile, SABIC is looking at overseas direct investment. "We are investigating petrochemical and derivative [investment] opportunities in any of five continents or a combination thereof," says Nojaidi.

Earl Anderson



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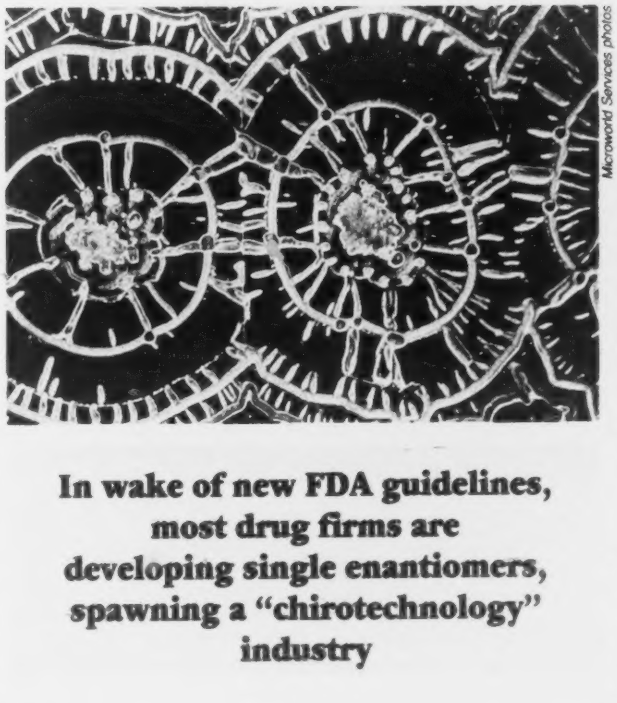


Microworld Services photos

In wake of new FDA guidelines, most drug firms are developing single enantiomers, spawning a "chirotechnology" industry

Stephen C. Stinson,
C&EN Northeast
News Bureau

Development of chiral drugs got a big boost with the Food & Drug Administration's release this summer of its long-awaited guidelines for marketing of these drugs (C&EN, June 15, page 5). Chiral drugs that exist in two or more mirror-image forms (enantiomers) are frequently offered as half-and-half enantiomer mixtures (racemates). The issue is whether drug companies may market such compounds as racemic mixtures or must develop them as single enantiomers. FDA's position is that drug companies have the choice of whether to develop chiral drugs as racemates or as single enantiomers.

But interpretation of the guidelines will rest with individual FDA reviewers considering particular cases. And under the guidelines, drug companies will have to furnish rigorous justification for FDA approval of racemates. So to avoid unpleasant surprises, most drug companies have decided to develop only single enantiomers. And a few have issued instructions to their research departments to avoid asymmetric molecules entirely.

This evolving regulatory climate in the development of chiral drugs presents many opportunities to drug firms and their suppliers. The chief beneficiary may be the chemist, because resolution of racemates, asymmetric synthesis, and determination of enantiomeric content are chemical activities.

Consultant Enrico T. Polastro of Arthur D. Little International, Brussels, envisions a growing "chirotechnology" industry, whose development he likens to the biotechnology industry. Small startup companies are racing to achieve proprietary resolutions, asymmetric production processes, and enantiomeric intermediates and active drugs. Big drug firms and established fine chemicals producers are adding asymmetric chemistry to their repertoires. And universities are marketing licenses for relevant patents.

Richard L. DiCicco, president of the consulting firm Technology Catalysts International, Falls Church, Va., sees promise in "racemic switches." These are redevelopments of drugs now marketed as racemates to enantiomers. Many racemic drugs have patents that have expired or are running out, and drug companies can patent enantiomers of their racemic drugs to defend

Photomicrographs (these two pages) of crystals of L-ascorbic acid under polarized light

themselves against competition from generic drugs.

If the racemate is already approved by FDA, then less testing is needed to "bridge" the gap to the not-yet-approved enantiomer. DiCicco and others estimate that only four years and $3 million might be needed to get approval for a racemic switch, compared with 10 to 12 years and $240 million for a new chemical entity. At that rate, generic drug companies could steal a march on brand name drug firms by also switching racemates to enantiomers.

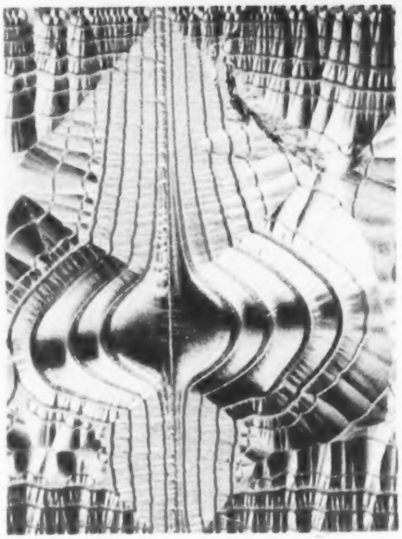
Yet another impetus that DiCicco sees for racemic switches is transdermal drug delivery (skin patches). This is because only active compounds would diffuse through the skin. In addition, he points out, patches containing only (S)-(–)-nicotine, for instance, are less irritating than those with the racemate.

Among classes of compounds DiCicco sees as candidates for racemic switches are cardiovascular drugs, nonsteroidal anti-inflammatory drugs (NSAIDs), central nervous system agents, antihistaminics, and prescription drugs being considered for eventual over-the-counter sale.

As for cardiovascular drugs, the other enantiomer of β-adrenergic blocking agents for hypertension often causes the drugs to have side effects, he explains. And a drug containing only the active enantiomer might result in a more potent drug being taken less frequently, therefore enhancing patients' compliance with doctors' orders.

Faster onset of action is the rationale for racemic switches of NSAIDs, DiCicco says. And central nervous system agents are potent drugs that are good candidates for transdermal delivery.

Among antihistaminics, racemic terfenadine causes side effects of dizziness and dry mouth. (S)-Terfenadine, however, may not have these drawbacks. Marion Merrell Dow, Kansas City, Mo., which markets the Seldane brand of racemic terfenadine, has issued a warning that the drug may cause life-threatening irregular heart rhythms when taken with the antifungal ketoconazole or the antibiotic erythromycin. This finding is so new that it is impossible to say whether the arrhythmias would be avoided with the enantiomeric drug.



As for the over-the-counter issue, DiCicco says that FDA is more likely to approve a switch from prescription to over-the-counter if the drug company has in some way developed a form of the drug that requires a smaller dose. An enantiomeric drug may do this.

Some implications of the emerging pharmaceutical chirotechnology are clearly emotional. Doctors are beginning to think that "enantiomeric is better." Sales representatives of one drug company, an industry observer tells C&EN, have urged doctors to prescribe one of its drugs that is not chiral, because "it's not a racemate."

Such marketing techniques also may impress patients. For ibuprofen, contained in Motrin, Nuprin, and Advil, the (S)-enantiomer is the active pain reliever and the (R)-isomer is inactive, but the (R)-isomer is converted to the (S)-isomer in the body. It may or may not be of greater therapeutic benefit that taking pure (S)-ibuprofen achieves higher blood levels of drug sooner. But drug companies may convince the public that S stands for "super," justifying higher prices.

Estimates of the size of the drug chirotechnology market vary. The differences depend on whether enantiomeric intermediates, chiral auxiliaries, bulk active drugs, or finished dosage forms are considered, according to DiCicco.

DiCicco argues that for potential participants in the new chirotechnology, sales of finished dosage forms such as pills or capsules from producer plants is the key number. He puts these chiral drug sales at $18 billion at present, growing to at least $40 billion by the year 2000. He disagrees with estimating the market using the value added by the asymmetry-inducing step.

First, he says, the big drug companies base their decisions to enter or expand on producer plant sales of dosage forms. Second, royalties in licensing agreements are based on a percentage of producer plant sales. Third, as DiCicco puts it, "Quantification of value-added chirality is a tedious analysis that misses the important trends affecting the business fate of chemical sup-

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Chemical "handedness" has its own language

Asymmetric. Completely lacking elements of symmetry. Some asymmetric molecules do not exist as enantiomers, however, and some molecules with simple axes of symmetry do exist as enantiomers (mirror images), so some persons prefer the term "dissymmetric."

Chiral. "Handed," having the characteristic of "handedness," which is having the potential to exist as two nonsuperimposable structures that are mirror images; not synonymous with the terms enantiomerically pure or optically active.

Configuration. Arrangement of atomic groups about a chiral center.

D or L. Absolute configuration of a molecule assigned according to experimental chemical correlation with that of D- or L-glyceraldehyde as the reference compound; often used with amino acids and sugars, but R and S are preferred.

d or *l*. Dextrorotatory or levorotatory according to experimentally determined rotation of the plane of monochromatic plane-polarized light to the right or left; since superseded by (+) or (–).

Diastereoisomers. Stereoisomers with two or more centers of dissymmetry and whose molecules are not mirror images of one another, for example, D-erythrose and D-threose; often contracted to "diastereomers."

Dissymmetric. Lacking an alternating axis of symmetry and so usually existing as enantiomers. Some prefer this to the term "asymmetric."

Enantiomers. Two stereoisomers whose molecules are nonsuperimposable mirror images of one another.

Enantiomeric excess (ee). Percent by which one enantiomer, E_1, is in excess in a mixture of the two; $ee = [(E_1 - E_2)/(E_1 + E_2)] \times 100\%$.

Enantioselectivity. Degree to which a chemical reaction produces one rather than the opposite enantiomer.

Meso compounds. Compounds whose molecules have two or more centers of dissymmetry but also have planes of symmetry and so cannot exist as enantiomers; for example, *meso*-tartaric acid.

Optical activity. Experimentally observed rotation of the plane of monochromatic plane-polarized light by a substance to the observer's right or left.

Optical isomer. Synonym for enantiomer; now disfavored, because most enantiomers lack optical activity at some wavelengths of light.

Optical purity. Percent of one enantiomer in a mixture of the two according to experimentally measured angle of optical rotation; not valid to describe enantiomeric purities determined by other methods.

R or S. Absolute configuration about a dissymmetric center, assigned by drawing the molecule according to specific conventions and finding whether a circle passes through certain atoms surrounding the center clockwise to the right (R, rectus) or counterclockwise to the left (S, sinister).

Racemic. Existing as a racemate, or 50-50 mixture of two enantiomers; also denoted *dl* (discouraged) or (±) (preferred). Racemates also are called racemic mixtures or racemic modifications.

Racemization. Conversion of one enantiomer to a 50-50 mixture of the two.

Scalemic. Existing as a mixture of two enantiomers in which one is in excess; coined in recognition that most syntheses or resolutions do not yield 100% of one enantiomer.

Stereoisomers. Compounds whose molecules consist of the same number and types of atoms with the same connectedness but different configurations.

pliers." Among such trends are the possibility that processes might change and that a certain enantiomeric intermediate might become obsolete. And fourth, an enantiomeric intermediate from a certain supplier might set a purity standard for production of a patented drug and thus determine producer plant values. While the drug patent is in force, the supplier could become very proficient at making the intermediate. When the patent for the drug expires, generic drug firms might find it hard to produce the drug without the intermediate from that supplier.

DiCicco notes that availability of in-

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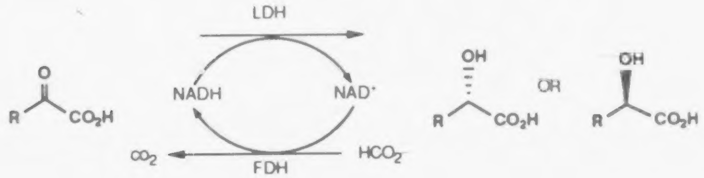

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termediates is often controlled by brand name drug firms and their subsidiaries. For example, in the fall of 1991, Zenith Laboratories, a generic drug company in Northvale, N.J., was planning to bring out a generic form of the cephalosporin antibiotic, cefadroxil. Bristol-Myers Squibb Co.'s patent on cefadroxil had expired.

To formulate and market the drug, Zenith needed bulk cefadroxil manufactured only by Gema of Barcelona, Spain. Gema is a subsidiary of Sandoz of Basel, Switzerland. Gema at first agreed to supply Zenith with the bulk cefadroxil, but at the last moment refused.

At present, the issue is confused, because Zenith, Sandoz, and Bristol-Myers Squibb are in litigation over whether use of the Gema bulk compound infringes Bristol-Myers Squibb patents still in force. This example, says DiCicco, bolsters his point about controlled accessibility to bulk actives and intermediates.

Many drug companies, therefore, are weighing whether to develop racemates or enantiomers and whether to make racemic switches. And many small startup companies dream of becoming the "Genentech of chirotechnology." But consultant William P. Jackson of Chem Systems, London, cautions that these drug companies have to weigh their choices carefully in terms of clinical benefit, marketing advantage, and regulatory considerations.

One question of clinical benefit is whether the enantiomer is superior to the racemate. As a case in point, Jackson cites the β-adrenergic blocking

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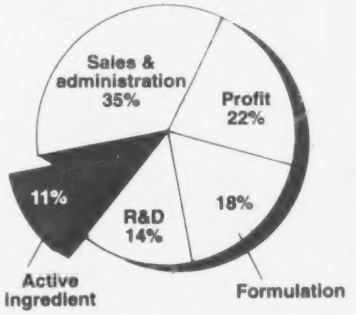

Note: Assumes price of $5000 to $10,000 per kg for patent-protected drug. **Source:** Chem Systems

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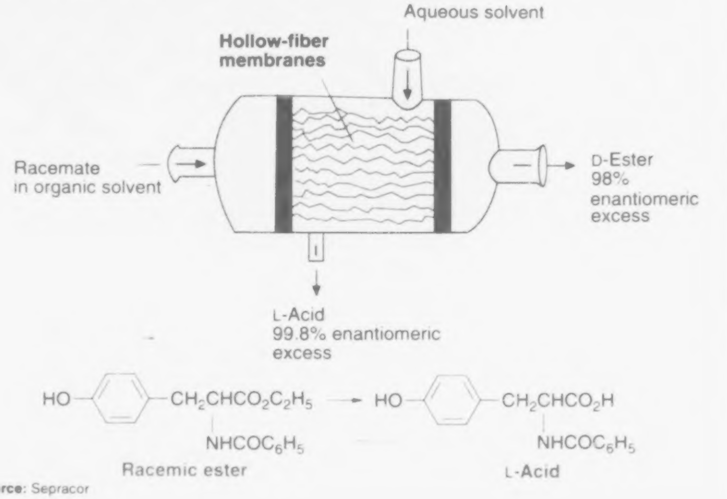
Hollow-fiber membranes resolve racemates continuously



Source: Sepracor

agent labetalol. This drug, designed to treat hypertension, is marketed in the U.S. by Schering-Plough, Madison, N.J.

In 1989, the company introduced (*R,R*)-(–)-labetalol in Japan with the generic name dilevalol. Dilevalol was thought to offer a desired specific antagonism of β_2 receptors in the heart with none of the α-receptor agonism of the racemate. But dilevalol was found to cause liver toxicity and was withdrawn within a year.

Another question Jackson raises is whether drug companies will really reap great profits from racemic switches. For example, the field of NSAIDs—ibuprofen, flurbiprofen, and others—is mature. This means there are so many competing drugs that a racemic switch would have to show some benefit, such as greater safety, to command a higher price. Furthermore, the imminent FDA approval of Pfizer's tenidap, which works by different mechanisms, represents such a significant advance in therapy of inflammatory disease as to make sales estimates for racemic-switched NSAIDs meaningless.

A third factor to consider, Jackson says, is that two enantiomers may have different pharmacological actions. For example, Janssen Pharmaceutica, Piscataway, N.J., is developing nebivolol as a β-blocker for hypertension. But whereas (+)-nebivolol is a β-blocker, (–)-nebivolol is not a β-blocker but is a vasodilating agent. Thus, by alleviating hypertension by two different mechanisms, the racemate may be superior to either enantiomer.

Finally, many industry observers believe that if the potency of an active enantiomer compared with a racemate of active and inactive enantiomers is such that the dose can be cut in half, the patient will benefit. The less drug taken, the less chance of side effects. Jackson cautions that this may not be so.

He poses the hypothetical case of a chiral drug that is degraded by metabolic reactions at a site distant from the asymmetric carbon atom(s). Both enantiomers would be inactivated at the same rate. Therefore, an inactive enantiomer may serve as a sacrificial substrate for degrading enzymes, prolonging the stay of the active enantiomer in the body. To achieve the same therapeutic benefit, the patient would have to take the same dose of costly enantiomer as of cheaper racemate.

But among Jackson's cited marketing advantages, half the dose of the drug, if possible, might be a good selling point with doctors. Another marketing advantage is patent extension. By obtaining or licensing a patent on one enantiomer of its own brand name racemate, a drug company gets an extension of exclusive marketing. It can promote the enantiomer while generic drug firms are limited to the racemate.

Though the cardiovascular calcium-channel blocker nifedipine is not a chiral compound, Jackson cites New York

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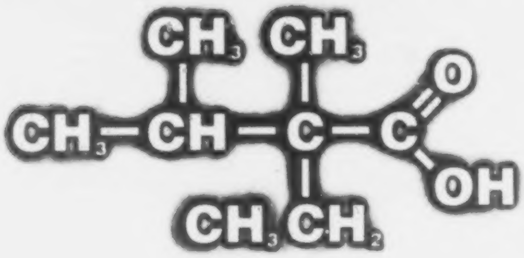

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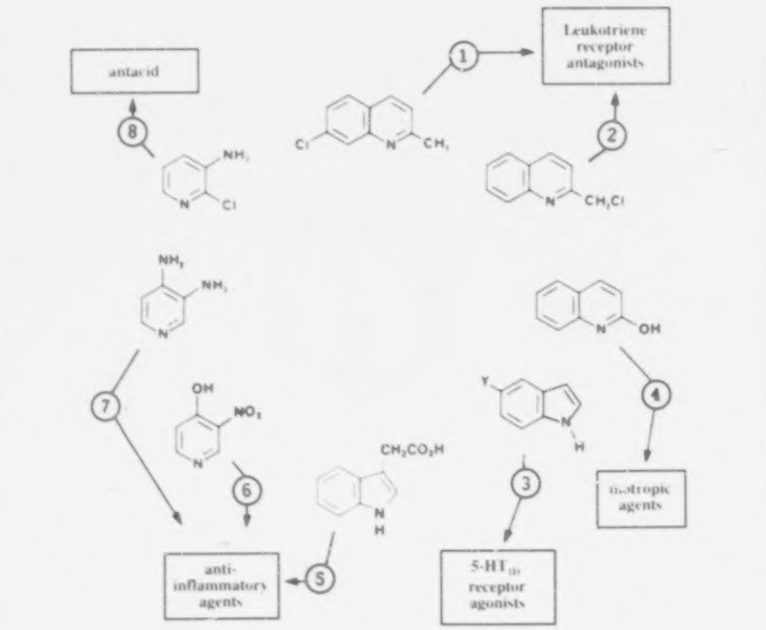

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World enantiomeric drug market is $18 billion

$ Million	1990 sales
Chiral antibiotics	$ 6,360
Captopril	1,501
Enalapril	1,482
Lovastatin	751
Diltiazem	746
Cefadroxil	690
Naproxen	686
Lisinopril	430
Timolol	297
Deprenyl	141
Methyldopa	140
Dexfenfluramine	52
Ethambutol	45
Transdermal nicotine	5
Sertraline	3
Other	4,630
TOTAL	$18,000

Source: Technology Catalysts International

City-based Pfizer's marketing strategy with its Procardia brand of nifedipine as an analogous example of the possibilities with chiral drugs. For many years, Pfizer marketed Procardia to treat angina. Then the company contracted with Alza Corp., Palo Alto, Calif., to design a multilayered, slow-release pill that would deliver nifedipine at a controlled rate by an osmotic mechanism. The new compound was developed.

Patients need take Procardia XL, as Pfizer calls it, only once daily. Pfizer also received FDA approval for hypertension as well as angina as an indication for use of Procardia XL. Now the company advertises to patients that if they take Procardia, they should ask their doctors if they are eligible for Procardia XL. Meanwhile, generic drug companies will be limited to nifedipine in "plain vanilla" for years.

Among the regulatory issues that concern Jackson is the cost of the tests needed to get approval for a racemate or an enantiomer. For a pure enantiomer, barring racemization or inversion in the body, simple chromatography is enough to follow plasma concentrations of the drug and its metabolites. For a racemate, simple chromatography must be followed by chromatography on asymmetric solid supports to learn about each enantiomer. As Jackson points out, such double analysis is costly.

Another of his regulatory concerns is

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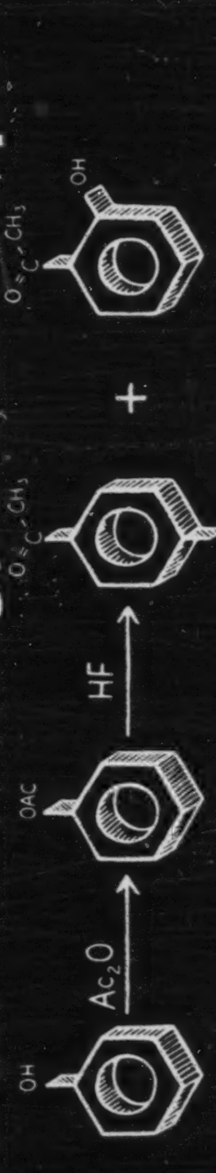

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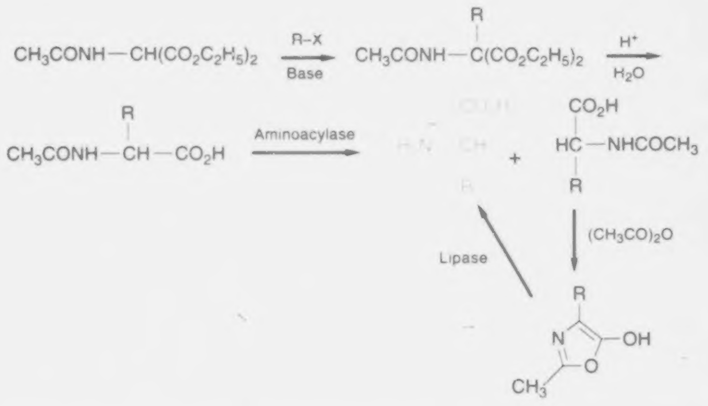
One-pot synthesis drives desired enantiomer formation



precedents in drug development. He cites the introduction of captopril in the enantiomeric form by E. H. Squibb & Sons of Princeton, N.J., as setting the tone for such angiotensin-converting enzyme (ACE) inhibitors. "Subsequent ACE inhibitors such as enalapril and benazepril have been developed in [enantiomeric] form," he says, "and it would be unlikely for a racemic/diastereomeric ACE inhibitor to be approved in the future."

Also important to Jackson is timing in development of a drug when a company decides whether to develop the racemate or one enantiomer. He cites SmithKline Beecham, London, and A. H. Robins Co., Richmond, Va., as examples of two companies who had to do costly backtracking in testing when they switched from racemates to enantiomers.

In the mid-1980s, SmithKline Beecham was developing cromakalim, the front-runner in a new class of compounds called potassium-channel activators. Such compounds have potential to treat angina, hypertension, and asthma, and perhaps glaucoma and impotence as well. The dextrorotatory isomer was found to have side effects, however, so the company switched to what is now called levokalim. The company is still working on FDA approval of levokalim to treat asthma, but lost about four years of clinical testing.

Robins was working on zacopride, a new type of antipsychotic drug that works by blocking type-three receptors of the neurotransmitter 5-hydroxytryptamine (serotonin). But where one enantiomer of zacopride is a $5HT_3$-blocker, the other is an agonist. American Home Products, New York City, acquired Robins in 1989 and transferred zacopride to its Wyeth-Ayerst Laboratories' subsidiary in Philadelphia for continued development as an enantiomer.

As the new chirotechnology industry takes shape to serve the drug industry, A. D. Little's Polastro advises companies to draw lessons from the history of the biotechnology industry. He notes that the biotech industry went through a shakeup in the 1980s when the expectation of quick returns changed to a more realistic estimate of the potential for profits.

Though Genentech and Amgen stand out as success stories of biotechnology, Polastro points out that the number of failures in that industry has greatly exceeded the number of successes. Some companies that did well were able to integrate their originally narrow biotechnological capabilities with a broader set of skills. Others concentrated on particular niches. And still others teamed up with larger companies.

In the chirotechnology industry, two firms that have managed to integrate production of enantiomeric intermediates with broad fine chemicals manufacture are Kanegafuchi Chemical Industry Co., Osaka, Japan, and DSM Andeno of Venlo, the Netherlands, and Elmwood Park, N.J.

Though good estimates are lacking, these two companies are believed to supply almost all of the merchant enantiomeric intermediates to the world drug industry, worth perhaps $1 billion per year. Another $500 million worth may be made captively by drug companies themselves. Industry observers say that Kanegafuchi is strong in microbiological methods of kinetic resolution and synthesis, whereas DSM Andeno excels in fractional crystallization of diastereoisomeric derivatives and asymmetric organic synthesis.

Ton Wijsman, vice president for DSM Andeno of the U.S., says the company started in chiral intermediates in the early 1980s by supplying *D*-(-)-α-phenylglycine as the side-chain for ampicillin. The company now resolves several hundred metric tons per year of this intermediate.

Since then have come D-(–)-*p*-hydroxyphenylglycine for amoxicillin, D-(–)-S-acetyl-β-mercaptoisobutyric acid for the angiotensin converting enzyme inhibitor captopril, (S)-indoline-2-carboxylic acid for perindopril, and enantiomeric glycidyl *p*-toluenesulfonates for the calcium-channel blocker diltiazem. And along with its growing expertise in the various chemistries, DSM Andeno has developed the capacity to analyze such compounds for enantiomeric excesses, Wijsman says.

One firm that looks to join hands with appropriate partners is Sepracor of Marlborough, Mass. The chirotechnology company has not waited for pioneering drug companies to develop racemic switches of their own brand name drugs but has moved to do so for them and to offer them (or their competitors) licenses. Sepracor also has invented or licensed a panoply of technologies to produce enantiomers generally.

For example, Sepracor has licensed both the asymmetric epoxidation reaction of inorganic chemistry professor Eric N. Jacobsen of the University of Illinois, Urbana-Champaign (C&EN, April 2, 1990, page 20), and the asymmetric dihydroxylation reaction of organic chemistry professor K. Barry Sharpless of Scripps Research Institute, La Jolla, Calif. (C&EN, July 22, 1991, page 19).

Among partnership agreements already reached, Sepracor has signed with Tanabe Seiyaku Co., Osaka, Japan, to supply kinetic enzymatic reso-

These drugs are best candidates for racemic switches

Cardiovascular

Acebutolol	Alprenolol
Atenolol	Betaxolol
Bisprolol	Bopindolol
Bucumolol	Bufetolol
Bufuralol	Bunitrolol
Bupranolol	Butofilolol
Carazolol	Carvedilol
Curteolol	Disopyramide
Dobutamine	Indenolol
Mepindolol	Metipranolol
Metoprolol	Nadolol
Nicardipine	Oxpranolol
Pindolol	Propanolol
Sotalol	Toliprolol
Verapamil	Xibenolol

Central nervous system

Dobutamine	Fluoxetine
Ketamine	Lorazepam
Meclizine	Oxaprotiline
Phenylpropanolamine	Thioridazine
Polycloramphetamine	Tomoxetine
Toloxaton	Viloxazin

Respiratory

Albuterol/ salbutamol	Metaproteranol
	Terbutaline

Anti-inflammatory and analgesics

Cicloprofen	Corticosteroids
Dihydroxythebaine	Fenbuphen
Fenoprofen	Flurbiprofen
Ibuprofen	Indoprofen
Ketoprofen	Minoxiprofen
Pirprofen	Steroids
Suprofen	Triamcinolone

Anticancer

Cytarabine	

Antibiotics, antiinfectives, antivirals

Ciprofloxacin	Norfloxacin
Ofloxacin	

Hormones, genitourinary

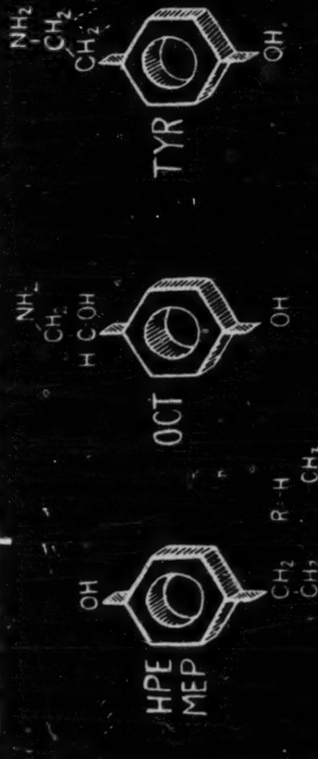
Benzyl glutamate	Butoconazole
Calcitonin	Estradiol
Fluorogesterone	Gonadorelin
Ketodesogestrel/ estrogen	Norgestrel
Progestin nitanol	Testosterone

Antihistamine and cough/cold

Astemizole	Terfenadine

Source: Technology Catalysts International

Developmental Intermediates



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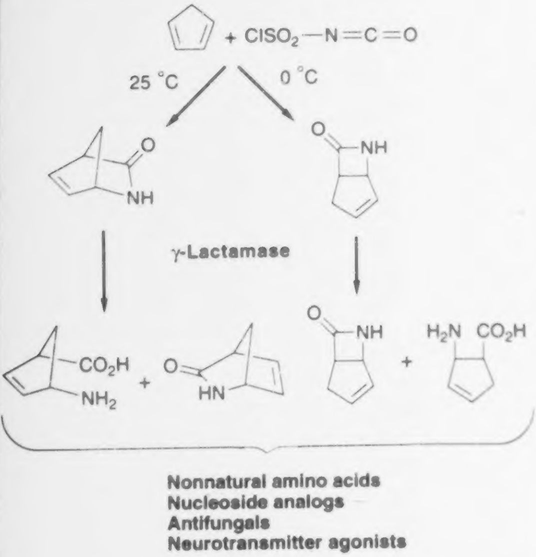
Cyclic lactam intermediates open doors to many enantiomeric drugs



lution technology to make an enantiomeric glycidyl derivative as a starting material for diltiazem. It also has licensed technology to Nagase & Co., Osaka, to make *S*-ibuprofen and an intermediate for captopril.

Racemic drugs of other firms for which Sepracor has worked out racemic switches to enantiomers are *S*-atenolol (the β-blocker Tenormin of ICI Pharma), *S*-nitrendipine (the calcium-channel blocker of Miles Laboratories), both *R*- and *S*-fluoxetine (the antidepressant Prozac of Eli Lilly & Co.), *S*-zopiclone (the sedative Imovane of Rhône-Poulenc), *S*-terfenidine (the antihistaminic Seldane of Marion Merrell Dow), *R*-albuterol (the antiasthmatic Proventil of Schering Corp.), *S*-flurbiprofen (the NSAID Ansaid of Upjohn Co.), and *S*-ketoprofen (the NSAID Orudis of Wyeth-Ayerst).

Sepracor says it has already reached one or more agreements with other companies to license these enantiomeric drugs but it is not revealing details of these pacts for now. The company has acquired expertise in all areas of resolution and asymmetric synthesis, tailoring these to achieve the most economical technology to make each compound.

One technique that gets a lot of use is immobilized enzymes in hollow-fiber membrane reactors. By this method, a solution of a relatively nonpolar derivative of a racemic compound in an organic solvent flows through the fiber bundle in a module. Next, an aqueous solvent flows over the outside of the bundle, and an enzyme immobilized in the fiber resin hydrolyzes the derivative enantioselectively to a more polar compound. The more polar enantiomer permeates the membrane, and the aqueous phase carries the hydrolyzed enantiomer away, while the unreacted other enantiomer is collected at the end of the fiber bundle.

Sepracor spokesmen say that single, laboratory-scale, hollow-fiber membrane modules have a capacity of resolving 165 kg per year at a molecular weight of 150. Capacities of whole reactors containing 20 production-scale modules are estimated to be about 100,000 kg per year.

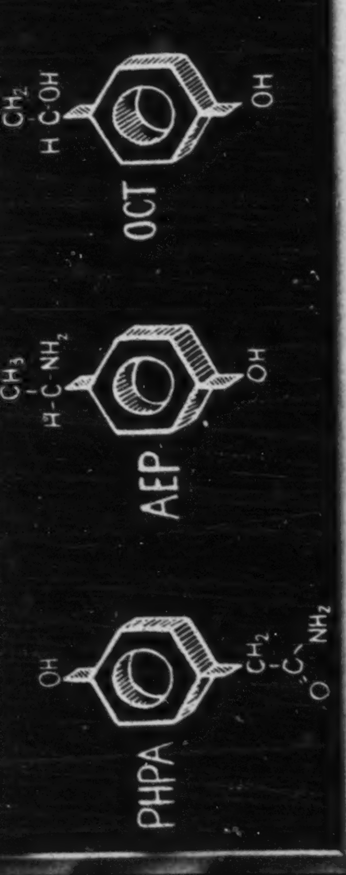
For example, a lipase immobilized in one version of the hollow-fiber membrane hydrolyzes the ethyl ester of *N*-benzoyl-D,L-tyrosine to the free L-acid in 99.8% enantiomeric excess while the D-ester is collected at the end in 98% enantiomeric excess.

In Cambridge, England, Chiros is a new company founded this spring to supply a broad range of synthetic organic and biological resolutions and asymmetric syntheses, mainly to the drug industry. Chiros is the successor firm to Enzymatix, whose chiral business it acquired. Commercial director Andy J. M. Richards says the company is in business both to "solve chiral chemical problems" for customers and to develop racemic switches.

Though intermediates are often specific to single drugs, chemists at Chiros have developed what they believe are generalized methods that open routes to whole classes of compounds. One of these is a one-pot amino acid synthesis. Another involves bicyclic lactam intermediates.

In the amino acid synthesis, the starting material is commercially available diethyl acetamidomalonate. Treatment with base and an alkyl halide produces the acetamidoalkylmalonate, and hydrolysis and decarboxylation yield the

Developmental Intermediates



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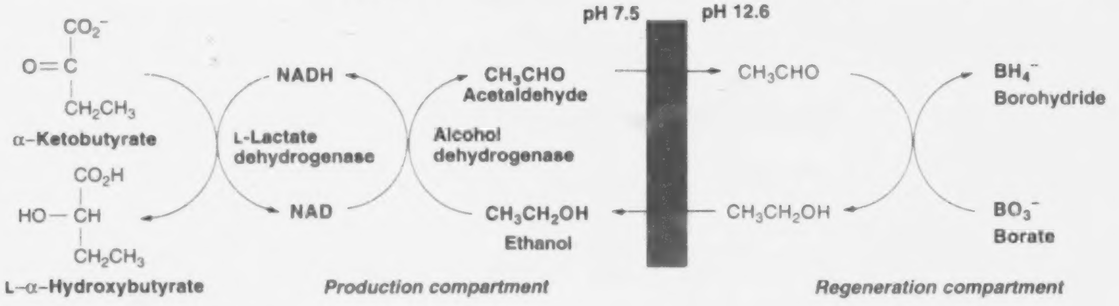
Permeable membrane isolates production medium from rigorous regenerating medium


pH 7.5
pH 12.6
CO2⁻
O=C
CH2CH3
α-Ketobutyrate
CO2H
HO—CH
CH2CH3
L-α-Hydroxybutyrate
NADH
L-Lactate dehydrogenase
NAD
CH3CHO Acetaldehyde
Alcohol dehydrogenase
CH3CH2OH Ethanol
Production compartment
CH3CHO
CH3CH2OH
BH4⁻ Borohydride
BO3⁻ Borate
Regeneration compartment

NAD = Nicotinamide adenine dinucleotide
NADH = Reduced NAD

Source: Bend Research

racemic *N*-acetylamino acid. An aminoacylase selectively cleaves this acid to one enantiomer of the amino acid, leaving the *N*-acetyl derivative of the other enantiomer. Unreacted *N*-acetyl enantiomer is then racemized by conversion to a symmetrical oxazoline, which feeds back to the desired amino acid enantiomer on hydrolysis with a lipase. Thus the process converges on the desired enantiomer without wasting materials.

In the cyclic lactam technology, chlorosulfonyl isocyanate adds to cyclopentadiene at 0 °C to give 7-azabicyclo[3.2.0]hept-2-en-6-one (the lactam of *cis*-2-amino-3-cyclopentenecarboxylic acid) and at 25 °C to yield 2-azabicyclo[2.2.1]hept-5-en-3-one (the lactam of *cis*-4-amino-2-cyclopentenecarboxylic acid). Chiros researchers have found microorganisms with γ-lactamase activity. These microbes open one or another lactam enantiomer selectively. The

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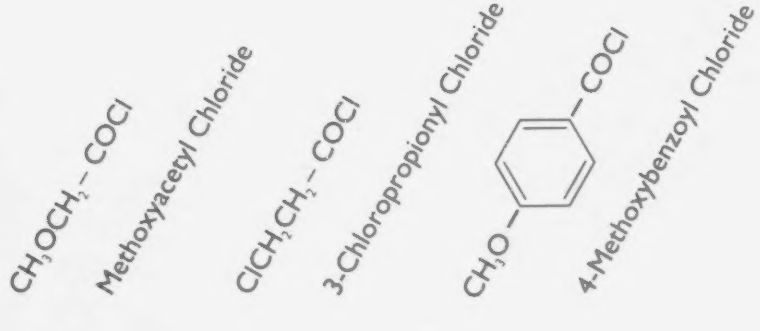
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various enantiomeric aminocyclopentenecarboxylic acids are useful for making nonnatural amino acids, nucleoside analogs, neurotransmitter agonists, and antifungals.

Where Sepracor and Chiros are examples of companies that nurture a stable of chiral technologies and do speculative research and development in search of partners, other firms are seeking niches in the new technology. For example, Celgene of Warren, N.J., has honed enantioselective enzymatic transamination to a fine edge and plans to supply enantiomeric amines as drug intermediates. The company is also developing parallel enzymatic techniques for other compound types.

At Bend Research, Bend, Ore., the emphasis is on selectively permeable ("permselective") membranes. Researchers there devise resolutions and asymmetric syntheses, driving reactions on one side of the membrane by means of complementary reactions in the other compartment.

Newport Synthesis Ireland, Dublin, sells and uses 100-kg quantities of enantiomeric auxiliaries. Enantiomeric auxiliaries are compounds that users bind covalently to substrates to induce asymmetry in later chemical steps. The auxiliaries are then cleaved.

And at Chiros, researchers seek to join enzymatic biotransformations to synthetic organic chemistry. The results are processes that are more economical than either type alone.

Celgene has isolated a number of proprietary transaminases from microorganisms, according to senior vice president Sol Barer. These are available in forms that make either the (R)- or (S)-amine. And transaminases can be used either to synthesize one amine from the corresponding aldehyde or ketone or to resolve a racemic amine by converting the unwanted enantiomer to a carbonyl compound.

For example, synthesis of either enantiomer of α-phenethylamine begins with acetophenone as substrate, a large excess of a low-cost amine donor such as propylamine, and either the (R)- or (S)-version of transaminase enzyme. The transaminase mediates conversion of the reactants to propionaldehyde and an almost 100% yield of *(R)*- or (S)-α-phenethylamine in greater than 99% enantiomeric excess based on the amount of acetophenone used.

Sometimes, however, the transaminase

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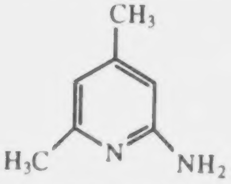
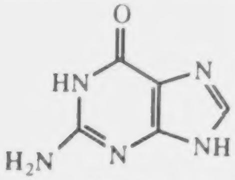
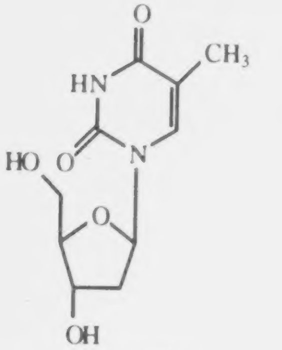


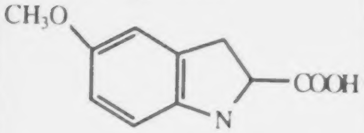
2-amino-4,6-dimethylpyridine



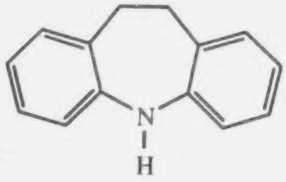
Guanine



Thymidine



5-methoxyindole-2-carboxylic acid



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does not have absolute enantiospecificity for the substrate used. In that case, the resolution mode is preferred.

For example, the (*S*)-aminotransferase gives only 93% enantiomeric excess of (*S*)-1-phenyl-3-aminobutane from 1-phenyl-3-butanone substrate. In the resolution mode, the ketone is first reacted with ammonia and hydrogen catalytically (reductive amination) to give racemic 1-phenyl-3-aminobutane.

Now the racemic amine is combined with the (*R*)-aminotransferase and an amine acceptor such as pyruvic acid. The transaminase catalyzes conversion of the (R)-amine to ketone, leaving the amine enriched in the desired (S)-enantiomer.

The (*R*)-transaminase still lacks complete enantiospecificity, however. So if the reaction were only run to 50% conversion, the (S)-amine would be contaminated with a small amount of unwanted (R)-enantiomer. In actual practice, the reaction is run to 58% conversion. This raises the enantiomeric excess of (S)-amine to greater than 99%, though some of the desired (S)-amine is converted to ketone.

There is no real loss, however. All ketone made in the resolution step can be subjected to reductive amination to racemic amine, which is recycled through the enzymatic resolution step and eventually yields virtually 100% of enantiomeric amine based on ketone.

In other developments, Celgene is working on an aldolase technology to condense glycine with, for example, benzaldehyde to make enantiomeric β-phenylserines as side chains for penicillin- and cephalosporin-type antibiotics. Such compounds could be reduced to aminodiols or dehydroxylated to nonnatural amino acids for peptide syntheses.

Celgene seeks to work with customers to supply individual samples of enantiomeric compounds, develop new catalysts and processes, produce kilo to ton lots of intermediates, or furnish biocatalysts and technology for use in customers' own plants. Barer emphasizes that, once an enzyme is in hand, it can be used in conventional chemical process equipment. Also, processes developed in the laboratory can be scaled up to ton lots without changes in technology. Celgene has a license from the Drug Enforcement Administration to make and store arylalkanolamines that may be pharmacologically active.

Scientists at Bend Research also use

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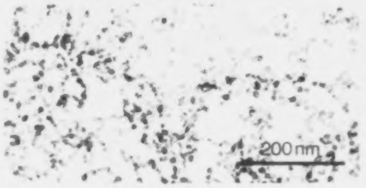

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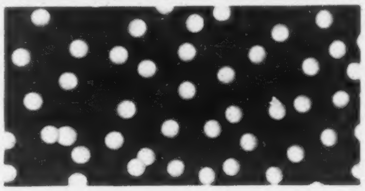

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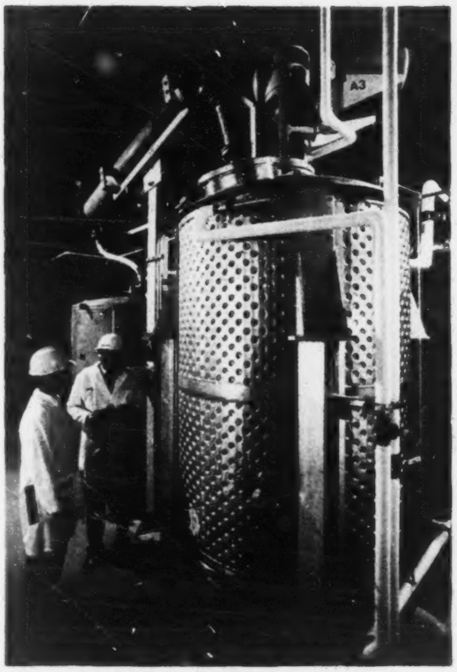
enzymes in their conversions. Because their enzymes sometimes depend on cofactors, they use permselective membranes to separate the delicate enzyme-cofactor chemistry from the strong reagents and severe conditions used to regenerate the cofactors. Development work at the company has been eased by the prior development of many cofactor regeneration reactions by organic chemistry professor George M. Whitesides and coworkers at Harvard University.

For example, the company has developed a reduction of α-ketobutyric acid to L-α-hydroxybutyric acid as a route to drugs through a versatile (S)-1-butene oxide. The reduction is catalyzed by L-lactate dehydrogenase using the reduced form of cofactor nicotinamide adenine dinucleotide (NADH) as the actual reducing agent. NADH is oxidized to NAD. NAD is regenerated to NADH using a complementary oxidation of ethanol to acetaldehyde, mediated by alcohol dehydrogenase.

To keep the regeneration cycle going and to avoid poisoning enzymes in the production compartment, acetaldehyde must be reduced again to ethanol. Bend Research uses sodium borohydride to reduce the aldehyde. But borohydride is a very powerful reducing agent that functions best in much more strongly alkaline solutions than those used for enzymes.

So the Bend Research process separates the borohydride reduction with its pH of 12.6 from the pH 7.5 enzyme compartment by a membrane. Acetaldehyde is the only compound in the production compartment that passes through the membrane to the borohydride side, and ethanol is the only substance on the regeneration side that passes back through.

Bend Research also has developed resolutions of important alcohols based on permselective membranes. In a first


Celgene produces up to ton lots annually of enantiomeric intermediates in these reactors

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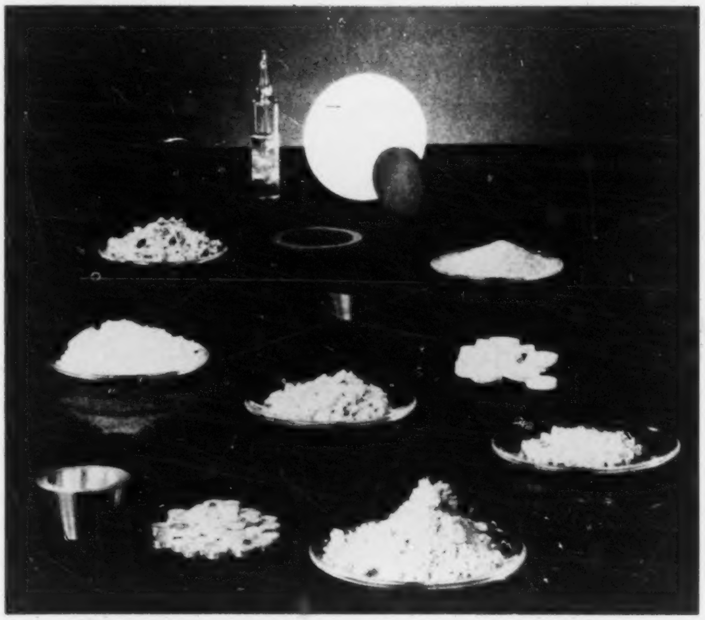

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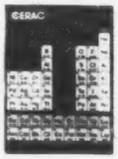

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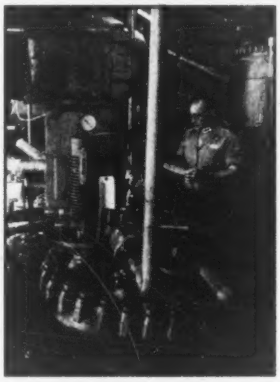

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Chiral auxiliaries now available in bulk quantities

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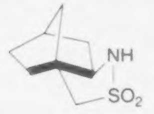
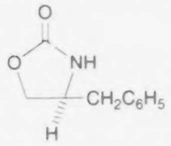


Bornane-10,2-sultam
[(2*R*)-isomer shown]

Aldol condensations



4-Benzyl-2-oxazolidinone
[(*S*)-isomer shown]

step with racemic 2-norbornenol for example, an (R)-lipase catalyzes esterification of (*R*)-2-norbornenol with butyric anhydride to give (*R*)-butyrate, leaving unreacted (S)-2-norbornenol in greater than 98% enantiomeric excess. The (S)-2-norbornenol passes out through a membrane, which rejects the ester.

But lack of specificity in the lipase leaves the ester in only 78% enantiomeric excess. To rectify this, the Bend Research process next uses the same lipase to hydrolyze the (R)-ester preferentially, also in a membrane process. The (*R*)-2-norbornenol passed by the membrane from the hydrolysis has greater than 98% enantiomeric excess. Alcohols resolved in this way also include β-quinuclidinol, 3-thianol, glycidyl and α-phenethyl alcohols, and mandelonitrile.

Among the chiral auxiliaries available in commercial quantities from Newport Synthesis Ireland are (2*R*)- and (2*S*)-bornane-10,2-sultam. This compound, first popularized among research chemists by organic chemistry professor Wolfgang Oppolzer at the University of Geneva, Switzerland, finds use in making derivatives of α-amino acid enantiomers.

Also available in bulk are (*R*)- and (*S*)-4-benzyl- and (*R*)- and (*S*)-4-isopropyl-2-oxazolidinones. These are familiar auxiliaries for enantioselective aldol condensations from the work of organic chemistry professor David A. Evans at Harvard University.

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Chiral drug conferences keep chemists up to date

Conferences have been established in the past few years to keep medicinal chemists current on issues of chirality in the drug industry. To date, three have been held, all in the U.K. The latest, called Chiral '92, was at the University of Manchester, England, March 24–25. The first conference in the U.S., Chiral USA '93, will be held at the Hyatt Regency Hotel, Reston, Va., May 6–7, 1993.

Chiral USA '93, which is sponsored by Spring Innovations of Stockport, England, will consist of a symposium and exposition. Registration will be at the Hyatt Regency on Wednesday afternoon, May 6, and attendance is anticipated to total about 1000, including exhibitors. The program is not yet final, but probably will consist of 20 papers being presented on Thursday and Friday covering such broad subjects as synthesis, resolution, catalysis, and commercial opportunities, and given by academicians, industrial scientists, and consultants.

Those in North America interested in attending Chiral USA '93 should contact Brandon Associates, P.O. Box 1244, Merrimack, N.H. 03054. Both the voice telephone and fax may be reached by calling (603) 424-2035.

Synthesis Ireland, Chiron Laboratories of Trondheim, Norway, is another European company whose enantiomeric products and expertise are available in the U.S. Chiron is represented by Davos Chemical Corp., Englewood Cliffs, N.J. Davos marketing manager Peter A. Demchko says his firm imports compounds made to order in Norway by asymmetric synthesis and/or resolution using synthetic chemical, enzymatic, and fermentation methods.

A company that has found a niche in classical resolution by diastereoisomeric crystallization is Zeeland Chemicals, Zeeland, Mich. The company is the former Hexcel Chemical Products Division, which was acquired by Cambrex Corp. in March. James K. Datson, business development manager at Zeeland, says the firm's main activity is use of enantiomeric acids for resolving racemic amines and of enantiomeric amines for resolving racemic acids.

Genzyme Corp., Cambridge, Mass., is another company that has found lipases able to catalyze difficult but desirable reactions. Scientists at the company recently reported a lipase from the yeastlike microorganism *Candida lipolytica* that hydrolyzes esters of α-methyl-α-amino acids. Such crowded molecular structures often make poor substrates for enzymes. Products of the hydrolyses are such enantiomeric drugs as carbidopa, which potentiates the action of L-dopa in Parkinson's disease, and methyldopa and metyrosine, which are useful for treating hypertension.

A new enantiospecific technology now appearing on the horizon is asymmetric amplification. This is the use of a catalyst whose chiral moiety is present in low enantiomeric excess, but which gives products that are of much higher enantiomeric excess.

The phenomenon would be of great benefit to the chirotechnology industry, because companies could use less expensive materials of low enantiomeric excess to make intermediates that are more valuable because of their high enantiomeric excess. Until now, though, asymmetric amplification seems to have been explored only by organic chemistry professors H. B. Kagan at the University of Paris-South, Orsay, France, and Nobuki Oguni at Yamaguchi University, Japan, working separately.

For example, Oguni has reported on the reaction of benzaldehyde with diethylzinc, catalyzed by (–)-1-piperidino-3,3-dimethyl-2-butanol (PDB) of low enantiomeric purity, to give (*R*)-(+)-1-phenyl-1-propanol. In six experiments, Oguni varied the enantiomeric excess of the PDB from 3.1% to 59.8%. The resulting enantiomeric excesses of the product ranged from 36% to 94%.

Kagan has a theory of how this could happen. The piperidino compound is a ligand (L) that complexes the zinc, he explains. In this and many other asymmetric catalyst systems, the complex is probably ZnL_2. If the nominally (R)-ligand (L_R) has only 50% enantiomeric excess, then there are actually three molecules of L_R for every one of L_S in the mixture. On average, there should thus be two catalytic complex types, ZnL_RL_S and $Zn(L_R)_2$. If for some reason the meso-catalyst ZnL_RL_S is much less active than its diastereoisomer $Zn(L_R)_2$, then the influence of L_R in the whole process will be greater than that of L_S—in other words, amplified. ☐

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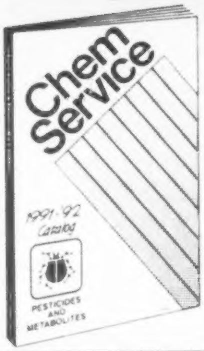

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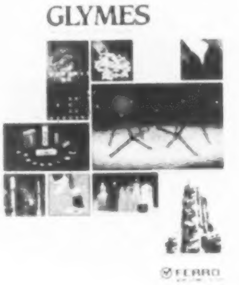

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CHEMICAL & ENGINEERING NEWS
C&EN
OCTOBER 5, 1992

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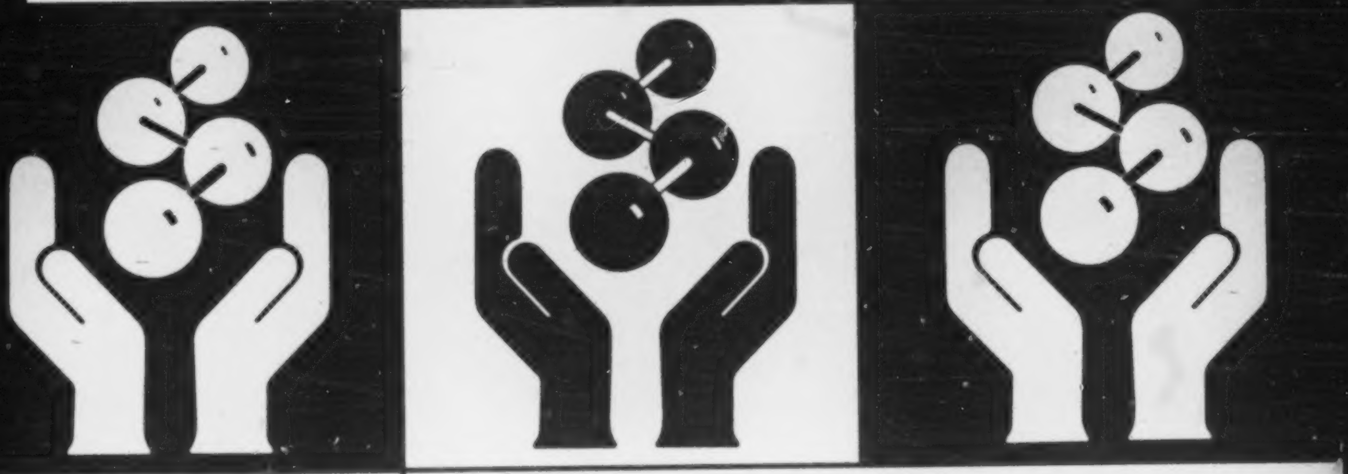

RESPONSIBLE CARE

Program to improve environmental performance challenges chemical makers

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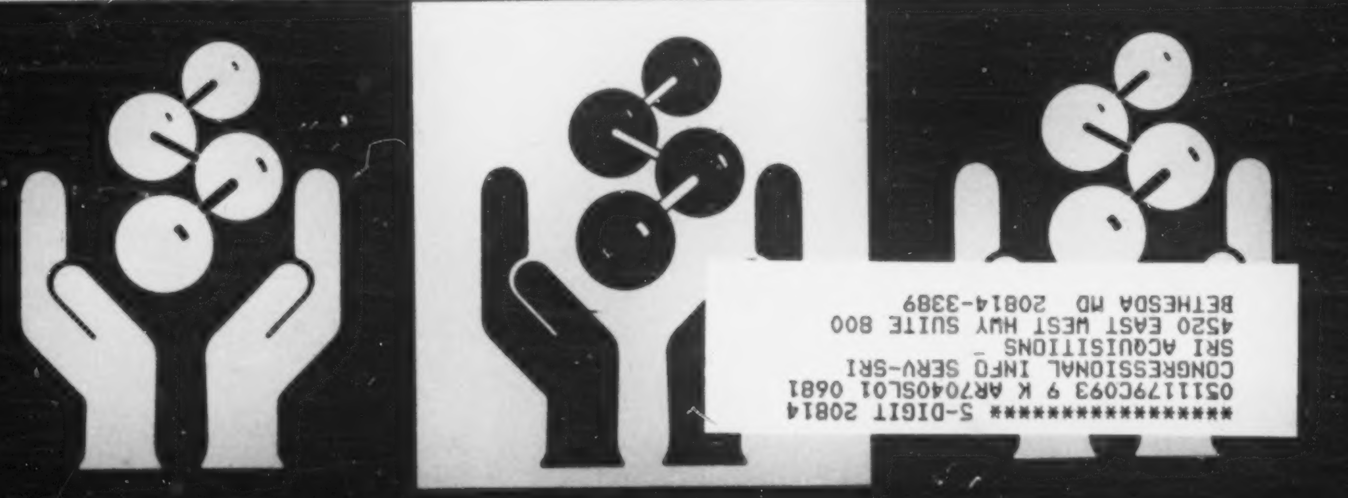

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CHEMICAL & ENGINEERING NEWS

C&EN

OCTOBER 5, 1992

NEWS OF THE WEEK

- EPA pulls proposed hazardous waste regulations that would have changed the way industry manages such waste; critics allege the move was politically motivated. Page 6
- U.S. launches Mars Observer spacecraft to explore the Red Planet's atmosphere, surface, interior, and magnetic field. Page 7
- Ozone destruction over Antarctica this year has appeared earlier, extended to lower altitudes, and covers a wider area than ever before. Page 7
- U.S. complacency about education needs to be shaken so continued progress can be made toward National Education Goals set by President Bush and state governors. Page 8

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ISSN 0009-2347

BUSINESS

Air Products is coming close to achieving the goals of its long-range strategic plan, although its new chairman does see the need for changes in some areas. Page 44

Japanese chemical firms are tightening their management of technology in an effort to remain competitive with their U.S. and European counterparts in the coming years. Page 46

Biotech industry had record revenues of $8 billion but incurred a net loss of $3.4 billion for the year ending June 30, according to a recent study. Page 48

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Heavy turnover is expected in Congress following next month's election, triggering major changes in many committees whose actions affect the chemical community. Page 50

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Researchers have bridged the blood-brain barrier by using a molecular packaging technique that enables "targetor"-peptide-cholesterol conjugates to slip past it. Page 57

Computational chemists are aiming to determine how best to integrate computer-aided techniques into the drug discovery process. Page 59

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Burke Laboratory, Dartmouth College's new chemistry building, has computer stations in both teaching and research labs and is designed to encourage faculty-student interaction. Page 59

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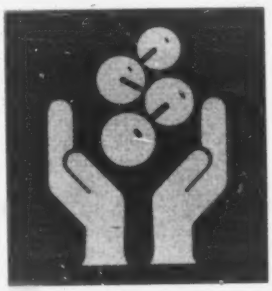

Chemical Manufacturers Association's Responsible Care program spearheads efforts to improve chemical industry's environmental, safety, and health performance to renew the public's trust. Page 13

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600, TDD (202) 872-4432
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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189, outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

Autoclave explosion results in injury

Wet-air oxidation of sodium zinc cyanide at 6000 ppm was carried out in a titanium autoclave tested to withstand 100 atm. The autoclave was heated to 200 °C. Seventy-five milliliters of the cyanide compound was injected into the autoclave with oxygen. Three such oxidations were successfully made at 200 °C and oxygen partial pressure of 3 atm. On the fourth such run, 11 minutes into the run, a violent explosion occurred. The gas-reactant valve had partly melted and fragmented. This valve was also made of titanium.

In a similar experiment with a similar autoclave, 100 ppm of 2,5-xylenol was tested at 180 °C and oxygen partial pressure of 4 atm. While adjusting the gas-reactant valve five minutes into the run, an explosion occurred where the SS-316 100-mL cylinder (meant for injection of the compound solution) was connected to the titanium gas-reactant inlet valve, producing third-degree burns over 40% of my body.

This disaster occurred while I was working on my doctoral project in the Bombay University department of chemical technology. No reference to similar hazards could be located in the literature.

V. R. Shenoy
Bombay, India

Chemical sensitivity, aversion

I am writing to add a few thoughts to the recent comments on multiple chemical sensitivity syndrome (C&EN, Jan. 20, page 3) and to draw a parallel between it and the acquired taste aversion phenomenon.

Acquired taste aversion has become recognized during the past 10 to 20 years. In general, it involves the development of an aversion to a foodstuff to which an organism has been exposed, even coincidentally, during an episode of ingestion-related trauma. Although the classic example of the phenomenon is the bait-avoidance behavior of rodents who have previously been sickened by poisoned bait, we are all aware of anecdotal reports of analogous responses by humans. Acquired taste aversions appear to have a significant physiological component; that is, they do not appear to depend on a conscious memory of the event, and they tend to lessen with time.

The credible, nonemotional reports of the multiple chemical sensitivity syndrome contain some interesting similarities. It is not a congenital problem and it, therefore, can be considered to be acquired at some point in life. It has been reported to have been caused by a triggering event involving an abnormal or excessive exposure to toxic materials through such events as chemotherapy, accidental pesticide exposure, or industrial chemical exposure, for example. Finally, the syndrome appears to ameliorate, with time, permitting victims to tolerate normal levels of odor.

I would like to encourage the chemical community to adopt a policy of referring to the syndrome as an acquired smell aversion or an acquired odor aversion. This would, in effect, replace the term multiple chemical sensitivity, with its implication of a physical illness caused by chemicals, with a considerably less pejorative name. The term aversion implies much more a psychological or psychosomatic condition rather than one that is physiological. We would also avoid the inaccurate relating of the syndrome to an allergic reaction as implied by the term sensitivity. The use and promulgation of the acquired aversion descriptor would permit sympathetic discussions with alleged victims while emphasizing that the phenomenon is an idiosyncratic response. I present these thoughts to help the chemical profession develop strategies to contend with this issue.

Fred W. Stone
Firmenich Inc.
Princeton, N.J.

International study

I applaud the recommendations made by ACS president Ernest Eliel (C&EN, Aug. 10, page 31) that ACS encourage and facilitate long-term visits to foreign countries by American chemistry students. I wholeheartedly agree that the possibilities

Continued on page 79

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municipality, or company that the plant will serve.

However, the company's environment and energy business continues to register a loss. In 1991, the operating loss for the unit totaled $7.2 million. And this continued through the first nine months of the current fiscal year, when environment and energy had an operating loss of $3.9 million.

Wagner says he is not dissatisfied with the unit's performance. Some markets, such as flue gas desulfurization, are growing slower than anticipated. But others, such as cogeneration, are moving faster. And, he says, as for the operating losses, these are all highly leveraged joint ventures and the interest charges are included in the operating results, lowering operating earnings.

Thus far, Air Products and its partners have invested more than $1.2 billion in six waste-to-energy, cogeneration, and flue gas desulfurization projects. All six are performing better than environmental standards call for, according to Wagner.

Wagner says his biggest challenge upon assuming the chairmanship is to continue the momentum that has been initiated under his predecessors. This includes globalizing the business, especially in the Far East and in Latin America and Canada; continuing to implement the goals of the strategic plan; expanding applications for both industrial gases and chemicals; and making the environment and energy segment a bigger contributor to the company.

Wagner does say, however, that there are some areas—mainly cultural—that, although he does not want to change them, he at least wants to broaden them. Although he considers the company a leader in safety, he believes there is a need for a greater commitment and sensitivity to the environment. In this area, he says, "we can do better."

He also thinks the employee population of Air Products needs to be diversified so that "employees will be similar to the world around them. This will mean a shift from primarily white male engineers to a broader spectrum—men, women, people from all cultures." A diverse employee population that is accustomed to working together in the U.S., he adds, also will be more effective in working with the different cultures in the other countries in which Air Products operates. "This is not a radical shift, but it is building on a culture that is already there," he says.

And he sees a need for more empowerment of employees—letting employees make more strategic decisions on their own. "We need to flatten our organization so that it is more responsive to the marketplaces that we are in," he says.

Wagner says these changes mainly come under the company's quality initiative and are largely cultural in nature. On the business front, there are few areas that he wants to alter. "From a business standpoint we have plenty on our plate," he says. "I see no need to look for dramatically different businesses. We like being in the position of having more opportunities than resources. It forces us to order our priorities and make better decisions." ☐

Japanese firms emphasize technology management

Of long-range strategies Japanese chemical companies are adopting to remain competitive in the 21st century, a beefed-up research and development effort ranks high on the list.

But implementing that strategy won't be easy for them. Smaller than many of the Western chemical companies with whom they compete, Japanese chemical companies have fewer dollars to spend on R&D. As a result, they will have to manage their technology more effectively, not just in the lab, but also along the entire chain from idea to marketplace.

Some signs indicate that they already are starting to do this. Shigeyoshi Takaoka, executive vice president of Kansai Research Institute, Tokyo, says Japan's chemical industry is accelerating its pace of innovation. He told the recent 2nd World Chemical Congress in Newport Beach, Calif., that most of its top executives understand clearly that the future growth of their companies—even their survival—depends on how well they can commercialize new products and processes based on their own R&D.

Among the technologies that he expects to emerge in the late 1990s and beyond are new materials, microelectronics, and biotechnology. Industries based on these technologies will grow much faster than gross national product and will be the driving force of world economic growth.

In Japan, for instance, Takaoka says such industries will account for 15 to 20% of GNP by the end of the 20th century. Advanced technological industries had only a 2% share of Japan's GNP in 1980.

However, for Japanese chemical companies to participate in this growth, they will have to use their limited R&D funds more effectively, he points out. Compared with U.S. and European chemical companies, or even with Japanese companies in other industries, each Japanese chemical company has less R&D money available.

That's because they are much smaller than their U.S. or European counterparts. Sales of Asahi Chemical, the largest chemical company in Japan, are only one fourth those of Germany's Hoechst and one third those of the U.S.'s Dow Chemical. Its net profit is only a fourth as large as Hoechst's or Dow's. Asahi's R&D spending ranges from 25 to 33% of its giant competitors.

Because there are so many small chemical companies in Japan, competition among them is keen. Price wars are common, and profits are lower than they are for U.S. and European chemical companies.

Takaoka notes that in the U.S., the top five chemical companies control 53% of their domestic market. In Germany, the top three command 70% of the market. But in Japan, it takes the top 10 companies to corral only 37% of the market. "There is no price leader in Japan to secure a reasonable profit for the industry," says Takaoka.

Japanese chemical companies do not export as much or produce as much overseas as their Western counterparts. Nor are they as diversified as Western companies, which have branched out into energy, pharmaceuticals, paints, and electronics. This leaves them more vulnerable to recession.

Among Japanese companies, Asahi "seems to be" the most diversified, says Takaoka. Of its 1991 sales ($7.2 billion), chemicals and plastics accounted for 38% and housing for 36%, with the remainder divided among fibers, pharmaceuticals, food, and others.

Today, Japanese chemical companies spend an average 4.9% of sales on R&D. Their R&D staffs average about 9% of total employees. Thus, R&D spending in the Japanese chemical industry is less than in the West, not only as a percent-

Chemical companies have ambitious plans for 21st century

$ Billions[a]	2001 sales target	Goal	Major strategies
Asahi Chemical	$24.6	Fifth largest in the world	Diversification into biotechnology, pharmaceuticals, functional products
Mitsubishi Chemical	$16.4	10th largest in the world, with 50% of sales from functional products	Information, electronics, new materials, pharmaceuticals, organic fine chemicals
Sumitomo Chemical	$17.2	International sales 30% of total	60% from specialty chemicals
Mitsubishi Petrochemical	$ 8.2	50% of sales from other than commodity chemicals	Fine chemicals, biotechnology, agrochemicals, new materials, new polymers
Mitsui Petrochemical	$ 4.1	Integrated chemical company, with 50% of sales from specialty chemicals	Agrochemicals, biotechnology, fine chemicals, optoelectronics, optical disks
Nippon Shokubai	$ 2.5	$655 million sales from new areas	New processes based on innovative technologies, information storage, optoelectronics, environment, fine ceramics, biotechnology

[a] Converted from yen at current exchange rates. **Source:** Kansai Research Institute

age of sales, but on an absolute basis as well.

Takaoka believes that all of these traits tend to make current research in the Japanese chemical industry inefficient. Of total R&D expenditures in the Japanese chemical industry, the top five companies combined spent 17.4% in 1986, whereas the German top three companies spent 67.4% and the top three chemical companies in the U.S. spent 25%.

What this means, says Takaoka, is that in Japan, R&D money is widely—and thinly—distributed among many small companies. It also means that the same kind of research probably is being done by many companies without each other knowing it. As a result, says Takaoka, Japanese chemical companies are wasting a lot of research money that they can't afford to waste.

That's why they are working hard to tighten up their management of technology as they make their long-range plans for the 21st century. These plans include not only more intensive R&D, but also globalization and diversification into such areas as specialty chemicals, electronics, biotechnology, pharmaceuticals, and optoelectronics.

To Takaoka, technology management means managing the entire chain of events, from idea to point of sale. "It is the way to get the largest profits from products with the least input of human and monetary resources," he says.

The job of managing technology starts with managing ideas. In the Japanese chemical industry, "need-oriented" ideas that flow from the marketplace are more important than "seed-oriented" ideas generated by research staffs.

Asahi Glass, for instance, has a market development center in each business division. Each center is staffed with about 30 professionals, consisting of about 70% technical and 30% marketing and sales people. The team feeds ideas obtained from the market back to each development center.

Takaoka also believes that the Japanese chemical industry tends to take on too many research projects. As a result, researchers and R&D dollars are so thinly distributed throughout the industry that the research can't possibly be very productive.

He says that too often in the past R&D ideas were decided not on their merit, but by the "egos and superficial perceptions" of top executives and research management. But now that R&D funds are becoming a larger part of their budgets, Japanese chemical companies are becoming much more selective in allocating R&D funds to new projects.

To reduce risk, many companies join projects sponsored by Japan's Agency of Industrial Science & Technology, which is part of the Ministry of International Trade & Industry. For chemical companies, two of its projects are most important. One is the National Research & Development Program, known as the "large-scale project." The other is the R&D Project on Basic Technologies for Future Industries, popularly known as the "Jiseidai project." In addition, about 30% of all Japanese companies work with national and public institutions, whereas 76% of them team up with universities.

To reduce time and money spent in applied research, many Japanese companies are automating their laboratories. And because most R&D efforts of Japanese chemical companies are market, or "needs," oriented, they tend to work closely with potential customers and suppliers at this stage of the development effort. About 45% of Japanese companies, says Takaoka, work with other Japanese companies.

After the applied research is completed, plant research or engineering personnel team up with the laboratory research staff to do the pilot-plant testing and development. In Japan, there is a close relationship between the two staffs.

In fact, Japanese chemical companies frequently rotate their development and plant staffs. Traditionally, says Takaoka, Japanese companies consider production technology to be critically important. And one of their strengths is that cooperation between the development group and production group is very smooth and "superior."

However, even if a company develops an idea this far, it won't be a success until the product is sold in large enough volumes to generate reasonable profits. To be successful in marketing and sales, Japanese chemical companies are taking several approaches. Some companies are making strategic alliances with other companies, including foreign companies, to take advantage of both of their strengths.

Others are adapting different tactics. Sanyo Chemical, for instance, has its "spin-off" system. So far, it has set up six spin-off companies as independent organizations to develop new businesses quickly and efficiently.

Sanyo's basic criteria for setting up a spin-off company is that the product must have a promising future and that the business cannot be managed effectively under the parent company's traditional management umbrella. The sales target for a spin-off company is 5 billion yen in five to seven years after startup. That's about $40 million at present exchange rates.

Sanyo's six current spin-off companies are in adhesives, health and medical products, functional polymers, imports, reactive resins, and optoelectronics. Typically, a spin-off company is staffed with 30 people from all of Sanyo's divisions, including R&D, production, and sales.

These companies are given full autonomy and responsibility for their own profit—and loss. Sanyo says that this arrangement shortens the time needed to develop and market a product and is better suited to training a staff. Because each spin-off company is small, it is more nimble than the parent. It can solve problems more quickly and effectively.

Toray, on the other hand, has a "new business" division that was started in 1971. Six business units are operating within it: carbon fibers, systems equipment, medical products, printing plates, pharmaceuticals, and optical products. In addition, Toray has a "new business promotion" unit that handles smaller volumes of new products.

The products that the new business division handles are developed by the R&D division and produced by the production division. Thus, the new business division concentrates on marketing and selling Toray's new products.

About 900 people work in the division, including about 250 in marketing. Each business unit within the division is responsible for its own financial performance.

Regardless of how it is done, top executives of Japan's chemical companies realize that properly managing technology is the key to their future growth, if not their very survival, says Takaoka. And now that they realize it, the philosophy and attitude of these top executives will play a big role in determining whether or not their companies' management of technology will eventually pay off on the bottom line.

Earl Anderson

Biotech industry revenues top $8 billion

The biotechnology industry continues to show tremendous growth and change, according to New York City-based professional services firm Ernst & Young's annual report on the biotechnology industry, "Biotech '93: Accelerating Commercialization." Revenues grew 28% and reached an all-time high of more than $8 billion for the year ending June 30, the report says. Product sales grew 35% and reached nearly $6 billion. However, sales still are attributable mostly to a few major products from a handful of top-tier companies. Overall, the 1231 companies surveyed reported a combined loss of $3.4 billion, an increase of 32% over the previous 12 months.

Whereas last year's Ernst & Young report focused on biotechnology's promises becoming realities, this year's report stresses that the industry is getting a "dose of reality." Uncertainties are higher than ever in the manner of volatile capital markets, patent disputes, regulatory issues and delays, and pending health care legislation. Yet, on the positive side, the federal government's stand on genetically engineered foods is expected to open the gates for agricultural biotechnology companies.

"Macrotrends" are becoming more important in determining the direction of the industry, than "microevents," or isolated company events, which often distract attention, says G. Steven Burrill, national director for Ernst & Young's San Francisco-based high-technology industry services. In response, he adds, executives are developing creative strategies to accelerate commercialization. To put these strategies into effect, companies have record amounts of capital to support growth and development.

During an 18-month public financing window that encompassed 1991 and the first half of 1992, 131 companies raised a record $5 billion through initial and followup offerings. In comparison, $3 billion was raised by companies during the decade of the 1980s. The financing window has since closed with stock prices falling precipitously in mid-1992.

Despite this, the market capitalization for the biotechnology industry remains at about $50 billion, up from $35 billion last year, but down from a midyear high of about $60 billion. A recovery in the financial markets is not expected for at least six months, says Burrill, and more likely not until the summer of 1993. But between $500 million and $1 billion in venture capital may be available for startup companies, because investors raised new funds during the stock market's earlier highs.

Another important factor this year, highlighted by the Presidential election, is the effect of politics on the industry, says Kenneth B. Lee, national director for life sciences industry services at Ernst & Young. The dialogue around major issues of health care reform and funding, the U.S. federal deficit, research funding, the role and effectiveness of regulators, tax initiatives such as capital gains, and international trade has a dramatic, and until resolved, uncertain effect on biotechnology.

Ann Thayer

Industry shows overall growth despite net loss

	Public companies			Industry total		
	1991–92	1990–91	% change	1991–92	1990–91	% change
Product sales ($ billions)	$ 3.4	$ 2.6	31%	$ 5.9	$ 4.4	35%
Revenues ($ billions)	$ 4.5	$ 3.5	29	$ 8.1	$ 6.3	28
R&D spending ($ billions)	$ 2.3	$ 1.5	54	$ 4.9	$ 3.4	42
Net loss ($ billions)	$–1.4	$–0.9	60	$–3.4	$–2.6	32
Stockholders' equity ($ billions)	$ 8.2	$ 4.5	83	$13.6	$10.7	27
Number of companies	225	194	16	1,231	1,107	11
Number of employees	37,000	33,000	12	79,000	70,000	13

Note: Fiscal years ending in June. **Source:** Ernst & Young

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CHEMICAL & ENGINEERING NEWS

C&EN

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Thermal spraying among industry's fastest growing segments
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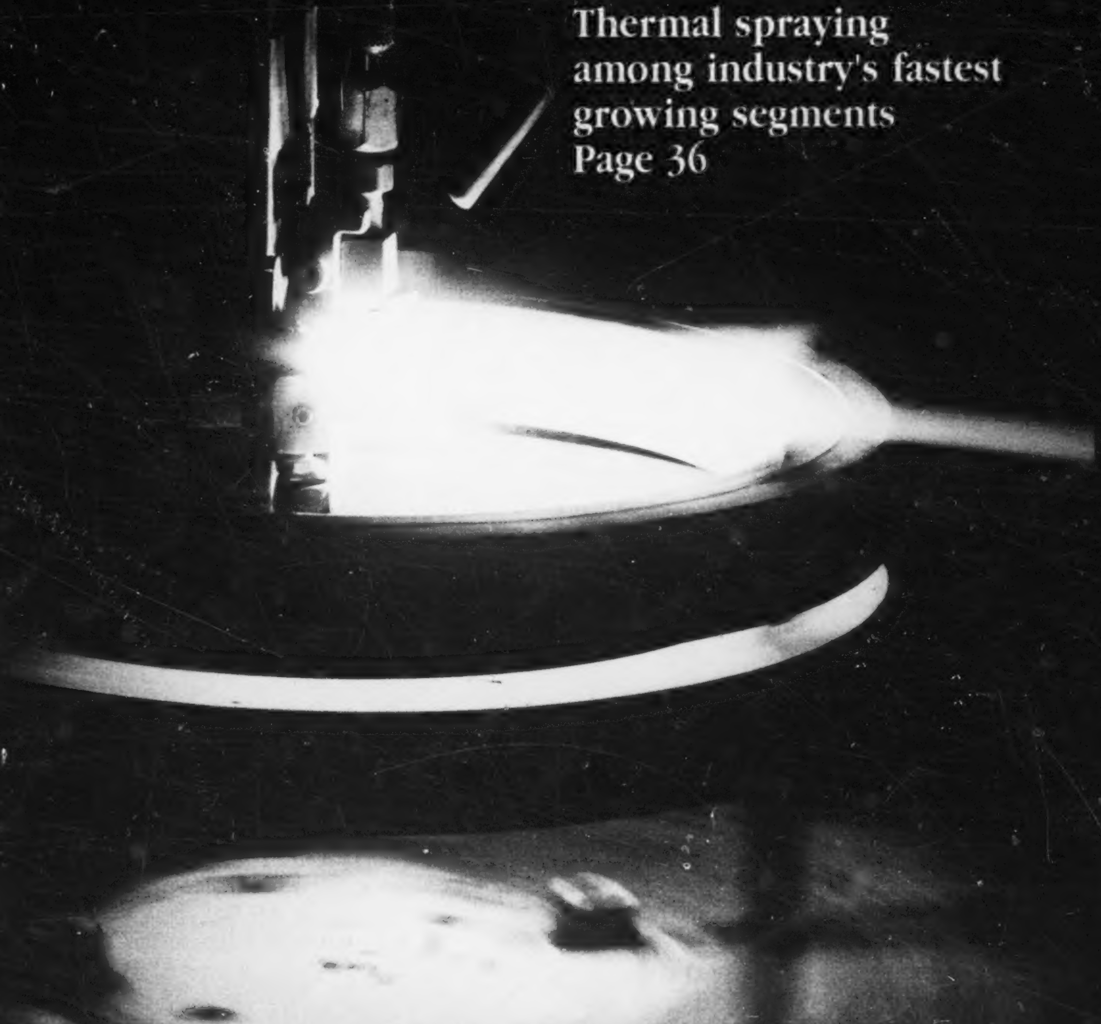

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CHEMICAL & ENGINEERING NEWS

C&EN

OCTOBER 12, 1992

NEWS OF THE WEEK

- President Bush has waived volatility restrictions for reformulated gasoline, encouraging the use of ethanol in gasoline. Page 8
- Congress' final days were marked by a frenzy of activity, with the Senate approving an energy bill but still at work at press time on a major tax bill. Page 9
- Downsizing of research labs, other drastic shifts in science are forecast by former science adviser Edward David Jr. Page 9
- Dutch scientists plan to probe the feasibility of raising the ground level along the coast by converting subsurface limestone to gypsum with sulfuric acid. Page 10
- Ernest Volwiler, president of the American Chemical Society in 1950 and retired chairman of the board of Abbott Laboratories, is dead at 99. Page 10

COVER: Metco plasma gun sprays aluminum-bronze soft bearing coating inside the bore of piston guide

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ISSN 0009-2347

BUSINESS

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
Robert H. Marks, Director, Publications Division

PUBLISHING BOARD: Ned D. Heindel *(Chairman); Board of Directors Chairman:* Joseph A. Dixon, *President:* Ernest L. Eliel; Richard L. Deming; Judith C. Giordan; William P. Jencks; and Gary J. Long

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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
(For list of offices see page 107)
Office of Ombudsman: (800) ACS-5558, No. 8–5
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LETTERS

Scientific smokescreen

I take strong exception to the letter of Edwin A. Matzner (C&EN, Sept. 7, page 4), in which he more or less encourages the media to let us "experts" in the sciences handle the decision-making process involved in applying or developing technologies. I would like to point out that scientific "objectivity" and "logic" are often merely smokescreens behind which lurk personal, professional, and political ambitions.

May I use as examples the recent spate of government and society reports that predict a dire shortage of scientists and engineers in the near future and that encourage massive increases in federal spending on research and education. More knowledgeable persons than I have debunked the underlying statistics and economic assumptions of these reports, but I would like to add my own personal observation: I seem to be a member of a growing host of young and talented scientists who are unable to find professional employment in our fields of specialization. I, and many of my peers in similar situations, view such self-serving proclamations with increasing cynicism and disbelief.

I, for one, welcome the scrutiny of the media, despite its numerous faults and excesses. The increasing number of media reports about scientific fraud, misconduct, and pork-barrel funding indicate that the primary problem facing science today is not personnel shortages or decreasing levels of funding, but is in fact hubris.

Michael J. Sherrod
Farmington, Me.

Science, technology, and society

Your report on the symposium at the national meeting on "scientific illiteracy" (C&EN, Sept. 14, page 31) highlights a new and pervasive problem within the science community. In research, the problem is reflected in the particularly American habit of ignoring the literature, difficult as it is to keep up with all of it. It is not, however, at all difficult to capture much of the enormous value in knowledge available in three telephone calls and a single computer search. Indeed, as scientists, we should be very aware of the public money we waste when we reinvent wheels or rediscover the well known.

Around 1970, groups of scientists at Stanford; Cornell; Penn State; and the State University of New York, Stony Brook, among others, caught up in one of Rupert Sheldrake's morphogenetic fields, became aware of the failure of the college system to make an impact on the general student's knowledge of both science, and even more pressingly, technology, and to put them into the context of society, started on those campuses what has become the "Science, Technology, and Society" (STS) movement. This has led to the institutionalization on several dozen campuses of our most prominent universities and colleges of departments or interdisciplinary units of STS. The movement entered the K–12 system a decade later and is today by far the most widespread reform of science education in schools. It is a genuine grass-roots megatrend. Professionals from all disciplines, university faculty, K–12 teachers, industrial researchers, and public interest activists have been meeting together (a sine qua non) regularly for over two decades to address the problems some of your speakers and audience seem to have rediscovered—scientific illiteracy. Actually, a decade ago, after many symposia, some under the American Association for the Advancement of Science aegis on "scientific illiteracy," the preferred term for what all citizens should know about science and technology, became "technological literacy."

There exists today a professional society, the National Association for Science, Technology & Society (NASTS); a journal, *Bulletin of Science, Technology & Society;* and an annual meeting held every year in Washington, D.C. The 8th Annual Technological Literacy Conference will be held Jan. 15–17, 1993.

Occasional symposia at single professional society meetings are excellent for stimulating some more scientists of that

Letters to the Editor

C&EN encourages readers to contribute to this letters section. However, please keep letters reasonably short—400 words or fewer. Because we receive a heavy volume of letters, persons writing letters are limited, as a general rule, to one letter within any given six-month period.

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Sagging U.K. Chemical Industry Expected To Turn Up This Year

■ ***Strong pharmaceutical sales and reorganization of the government's trade department will give lift to industry***

Patricia L. Layman, C&EN London

Chemical industry analysts tend to be a gloomy and cynical lot. But these days, when they say of the British chemical industry, "It's on its knees," there is an underlying sense that that's not a far-fetched exaggeration of the state of health of the industry, which last year accounted for sales of $51 billion.

In a way, a robust chemical industry would be surprising: The U.K. is one of two countries in Europe (the other is Sweden) whose economies are actually contracting rather than growing, declining at a rate of 0.8% so far this year. According to Dun & Bradstreet, Britain has recorded more than 46,000 business failures in the first nine months of 1992, almost as many as in the entire year of 1991. Unemployment is running at nearly 10%, with 2.8 million people out of work. Basic industries that are heavy customers of the chemical industry—for example, housing and construction, automobiles, consumer durables—are in a woeful state. The sectors of the chemical industry supplying those industries are, in turn, experiencing slumps.

On the other hand, the largest single sector of the British chemical industry, pharmaceuticals—which make up roughly one third of the industry's total sales—is basking in strong sales, growing markets, and expanding research and development commitments.

Henderson: lower interest rates needed

After having toured the country's chemical companies, Ray R. Knowland, president of the U.K.'s Chemical Industries Association (CIA), and retired chairman of BP Chemicals, said the basic chemicals side of the industry is trying to work out "which year the recession is going to lift." Pharmaceutical producers, however, can respond: "Recession? What recession?"

In fact, the chemical industry this year is expected to show an overall growth in production of as much as 1% over 1991, because of the strong growth of the pharmaceuticals sector. Without that support, the industry's production would be down 1.5 to 2%, according to current estimates.

Many of the problems facing the U.K.'s economy have followed from high interest rates (more than 10% during the past several years) and a strong pound sterling rate. High interest rates have been regarded as a major squelcher of economic activity—house sales and construction, auto financing, and the like. And the high cost of the pound, particularly against a much weaker U.S. dollar, has cut into exports while encouraging imports, affecting domestic industrial output.

However, the economic storms of September, which took Britain and Italy out of the European rate mechanism within the European Community and devalued the pound, the Italian lira, and Spain's peseta, were welcomed as a relief by the business community in particular (C&EN, Sept. 28, page 7).

Although chemical industry managers support the goal of eventual monetary union, with stable currency conditions, they agree that, for now, it is more important for Britain to tend to strictly domestic concerns. Lower interest rates to spur economic growth came almost immediately, with a base rate of 9%. The weaker dollar was expected to almost immediately translate into improved export opportunities for the chemical industry.

"We desperately need a stimulus to growth from lower interest rates, which would help to ease both the debt burden being carried by corporations and individuals," says Sir Denys Henderson, chairman of British chemicals giant ICI. "Action has also clearly been needed to assist U.K. exports, which have been suffering from the unrealistically high value of sterling. I am mightily relieved that the decision has been taken to float sterling. It will certainly make life less difficult for those of us who are substantial exporters."

Exports are important for the chemical industry—and for the U.K. Last year, the industry posted $24.7 billion worth of exports, compared with imports of $19.5 billion. That made chemicals the country's top export earner in the manufacturing sector in 1991, according to CIA, which points out that 48% of chemical sales were export sales. Of those, some 55% went to other EC countries.

Its trade record helps reinforce the chemical industry being part of an increasingly global industry—and it must compete on a global basis. Governmental attitude becomes increasingly impor-

Scottish chemical industry has distinct differences

It's not quite the Gulf Coast of Britain, but the Forth River in Scotland has managed over the years to become the center of the chemical industry in that country.

At Mossmorran, just over the Firth of Forth, north of Edinburgh, lies Exxon's massive ethylene cracker, which, in turn, is adjacent to Shell's natural gas liquids plant. Further up the river, west toward Glasgow, is Grangemouth, a town with chemical ties since the 1920s. There, more than 5000 workers are directly employed by the industry and another 10,000 in the broader economy. In fact, according to the Grangemouth Development Group, the chemical industry accounts for almost 48% of the Forth Valley gross domestic product.

And just as the Scots have proudly and determinedly kept their national identity and burr, the chemical industry in Scotland has some distinct differences from that of England and Wales.

"The English chemical industry is different than the Scottish," if in no other respect than its larger captive customer base, says Ted Ferguson, general manager for BP Chemicals at Grangemouth. "Look around Scotland—who's using our materials, our feedstocks? This spot has an advantage over Mossmorran in our downstream customers, all sorts of customers making their livings from the direct feedstocks from chemical plants in Grangemouth. There are no other capabilities like that in Scotland, but several in England—it has a larger pool to draw on."

As a result, Scotland has always looked for export markets, points out Del Blake, general manager of Exxon's Mossmorran plant. "We are not serving a Scottish market. We're not even serving the U.K. As a generality, we are serving Western Europe."

Notes Alex Salmond, leader of the Scottish National Party: "The Scottish economy is one of the export powerhouses of Europe—we are one of the strongest exporting countries in Europe. Scotland is competitive in international terms, not badly placed."

However, it faces stiff competition as a potential company site. As Blake points out, "ninety percent of the chemical industry in Scotland is made up of the big players—such as BP, ICI, Exxon, Rohm & Haas, and Glaxo. All of those companies have a choice as to where to put investments. Demand will generally be in mainland Europe—Benelux, France, Germany, for instance. All other things being equal, firms wouldn't necessarily put investment in Scotland.

"If you don't have a marketplace in your favor, you need to be competitive with elsewhere in Europe," he adds. "Why would people come to Scotland? From a strategic point of view, there are feedstock availability, distribution of production capability, and land availability."

Mike Andrews, managing director of Rohm & Haas (Scotland) and current chairman of the Scottish regional committee of the U.K.'s Chemical Industries Association, agrees. "A lot of companies have been here a long time, but some companies have come here for some of those very reasons," he says. "For example, there is the North Sea natural gas, for feedstocks. And there is availability of land for future expansion: Mossmorran, for example,

tant then and questions are raised. Is there an understanding of business needs, an understanding of the consequences of legislation affecting the industry? For the British chemical industry, the signs are increasingly positive.

This summer, for example, the government's Department for Trade & Industry (DTI) was reorganized by Michael Heseltine, secretary of state for trade, "to relate more closely to sectors of industry." Among the points to be emphasized at the time was the adoption of a sectoral approach to the industries for which the department is responsible.

"The new structure will allow for the establishment of some new divisions, and the recasting of some previously existing divisions, to establish a division dealing with industrial competitiveness," he says, "together with a range of sectoral divisions dealing with industries including chemicals and biotechnology, and steel."

Under the reorganization, one government minister is delegated to be responsible for the different sectors. There is a minister assigned, for example, to handle chemicals and biotechnology, as well as steel, metals and minerals, vehicles, aerospace, electronics and electrical engineering, and mechanical engineering.

CIA, for one, has welcomed the plan, seeing it as a means for the department to

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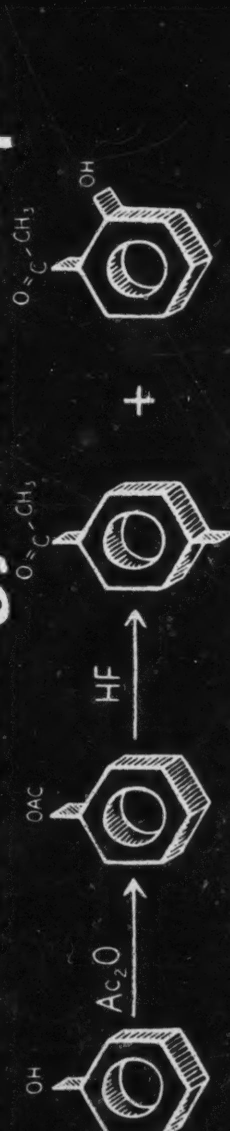

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was a greenfield site when Exxon built its cracker there in the 1980s."

Moreover, transportation links with the "rest of the world" are being upgraded, particularly rail. As Ferguson points out, a new railhead is being built southwest of Glasgow, that will provide improved, through service to the south of Britain and the Continent, when the Channel Tunnel is built. "That will give us direct links down there—it will be very important to us."

One of the major differences for industry in Scotland, compared with England and Wales, is the system of property taxes. The difference can be significant, indeed, says Exxon's Blake: "The rates we pay in Scotland are about £10 million (roughly $18 million). If this cracker were at Fawley (Exxon's cracker complex on the south coast of England), it would be about £2 million."

Adds Ferguson, the British government is promising to introduce uniform business rates throughout the nation, so, in time, this difference will be resolved. But for the time being, he notes, "It doesn't add to the attractiveness of Scotland."

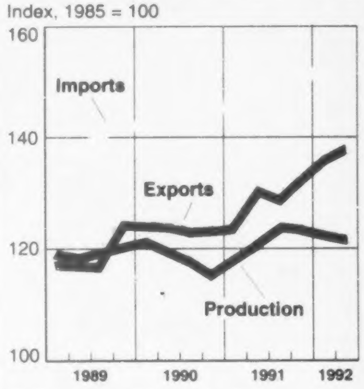
One of the advantages of Scotland, however, is that it is concentrated in a small region. Not only do chemical industry staffers meet regularly to provide guidance on implementing corporate Responsible Care programs, for example, but they also meet frequently with government officials, from local councils and groups to the British government's Scottish Office. Discussion points might include such things as tax rates and water and energy costs.

be more responsive to the needs of industry. The association's director general, John Cox, says,"I am pleased to see that DTI will have a minister who will take a personal interest in the needs of our sector, which is one of the most valuable contributors to Britain's balance of payments. I am particularly pleased to see that biotechnology is recognized as being important."

As Cox sees it, the reorganization signals a willingness by government to "achieve a dialogue in understanding the scientific decisions made, with full knowledge of the facts. A lot of that applies at the national level, but clearly, more and more at the European decision level," he points out. "That depends on the Council of Ministers, so we must make sure the ministers know on these few important issues, the full facts, and the consequences of their decisions—where the hidden advantages and disadvantages are, depending on how European laws are applied."

In part, the DTI reorganization comes in response to the abolishment of the National Economic Development Office (NEDO), a tripartite organization consisting of government, industry, and labor, designed to encourage different industrial sectors both within the U.K. and as international competitors. For political reasons the British government has decided to abolish the organization at the end of this year.

U.K. chemical output down, but exports and imports up

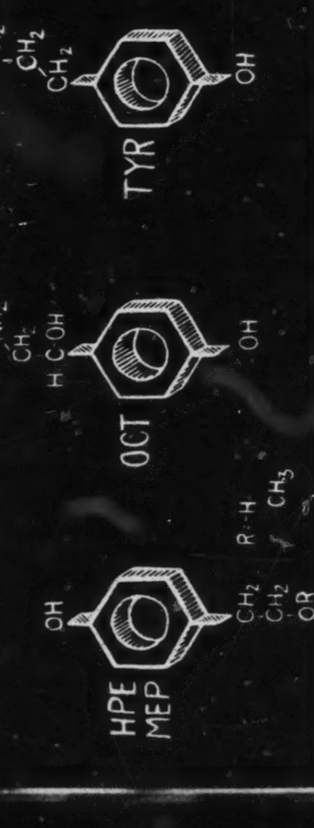


Source: U.K. Central Statistics Office

Pharmaceuticals account for third of chemical sales

$ Billions	1991 sales	% change 1990–91
Pharmaceuticals	$16.8	5.0%
Industrial specialties	9.2	na
Organics	6.1	5.0
Soaps, toiletries	5.1	−5.8
Plastics	3.1	−3.5
Paints, inks	3.1	−5.0
Dyes, pigments	2.6	0
Inorganics	2.0	−10.5
Household chemicals	2.0	na
Fertilizers	1.0	−9.0
TOTAL	$51.0	0.0%

na = not available Source: Chemical Industries Association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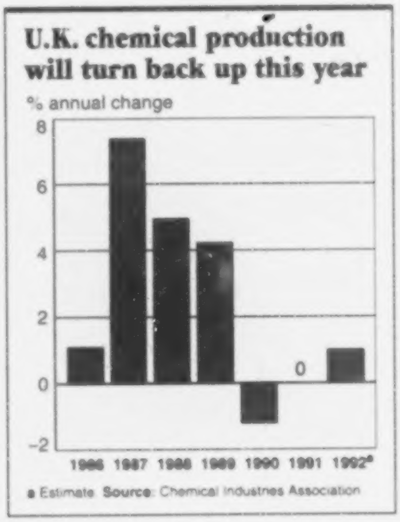


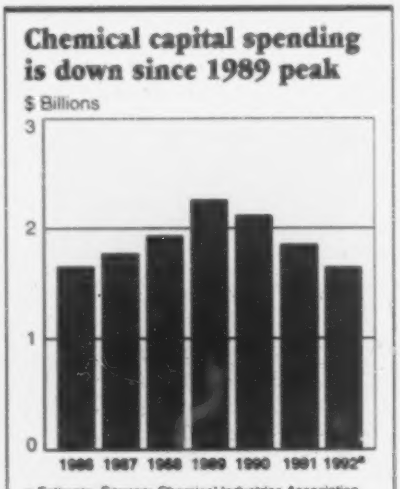
U.K. chemical production will turn back up this year

a Estimate. Source: Chemical Industries Association

One result has been to make the major organizations representing various industries that much more important for lobbying to government. That, in turn, is arousing an interest in the more specialized sectors of the industry, for more formalized representation before government.

Last month, for example, CIA president Knowland proposed a Specialized Organic Chemicals Sector Association, separate from, but integrated with and involved with CIA, with ready access to CIA's common services such as parliamentary and media affairs. In a way, this would replace the specialized organics group within NEDO, which had been one of its more active groups.

Among the lobbying grounds for CIA are the problems of energy costs and availability, particularly vexing for the U.K. chemical industry. Large electricity users, such as ICI, with its chlor-alkali operations, have already begun vigorous public campaigns to convey the message that U.K. power costs are disproportionately high.



Chemical capital spending is down since 1989 peak

a Estimate. Source: Chemical Industries Association

On the other hand, one area in which the industry must fight its own lonely battle is in recruitment into the industry. It's not a problem now, companies report, but they are worried about the pipeline of entering people—it is not filling up. In part, this reflects the low opinion held by the general British population of the chemical industry. But it also reflects what has been happening in the industry as well.

Employment in the chemical industry has fallen from 383,000 in 1981 to just under 300,000 this year. The annual graduate recruitment survey, published by CIA, shows that this year the industry expects to recruit 21% fewer graduates than last year. The reason given in this year's survey: depressed trading conditions worldwide.

Graduate recruitment by the chemical industry has fallen substantially from the high levels of 1989 and 1990, the survey indicates. Only in biological science does the decline appear to have halted. Chemists are the largest category of recruits, accounting for nearly 30% of the total recruited in 1992. The next largest category is chemical engineers, at 18%.

However, the results will strike a familiar chord with observers in the U.S. With graduate recruitment going down, students are reacting to this message of the marketplace, and opting for other careers. Careers in finance are particularly appealing in the U.K., whether in "the City," London's equivalent to Wall Street, or in the abundantly populated profession of accounting.

Industry is working with the education profession to train teachers, on the theory that that can help inspire scientific career choices later on in a student's life. Says Cox, "You won't have people in science at the university and college level, unless they have had exciting science at the younger levels.

"Our determination on educational issues is here to stay. For now, we are tending to attract and retain the talent we want—but we want it to be on a positive basis, not because there's a recession in the City. We want people to make this industry their first choice." ☐

SCI medalist airs views on industry issues

This week, H. Eugene McBrayer, former president of Exxon Chemical, will receive the Chemical Industry Medal. The American Section of the Society of the Chemical Industry (SCI) awards the medal for "conspicuous service to applied chemistry."

McBrayer succeeded Edwin C. Holmer as president of Exxon Chemical and like Holmer he is also now a recipient of the SCI Medal. McBrayer retired in 1990 after 20 years with Exxon Chemical and 37 years with Exxon Corp. During his career at Exxon, he served on the board of the Chemical Manufacturers Association (CMA), retiring from the organization after serving as its 1990–91 chairman.

In a recent interview with C&EN, McBrayer discussed some of the issues he sees as most important, including chemical industry credibility and the condition of science education in the U.S., two issues he says are intertwined.

McBrayer says that if the chemical industry is unable to attract capable people, the industry could well lose its innovative edge. The current climate of opinion is set against the chemical industry, he says, and, in turn, affects the educational choices young people make in selecting their careers.

The problem is not at the university level. In fact, there the technical level of achievement is "outstanding." However, in the lower grades science literacy is suffering. One reason, perhaps, is that the chemical industry has lost credibility. Increasingly, polls "find us more the source of problems than of solutions," McBrayer says.

The step the industry has taken in adopting its Responsible Care program, he says, will go a long way both toward changing public attitudes about the chemical industry and gaining wider acceptance for chemistry as an acceptable career path. McBrayer was involved in much of the early planning for the Responsible Care program, the industry's comprehensive commitment to health, safety, and the environment. It was during his tenure as CMA chairman that the organization instituted its $8.5 million advertising program to open a dialogue with the public about

PRODUCT REPORT

Paints and Coatings Sales Top $11 Billion

Thermal spray impinges on traditional polymer coatings; prices of titanium dioxide have moderated for now

Marc S. Reisch,
C&EN Northeast
News Bureau

Although actual industry shipments of paints and coatings may have declined in 1991, it may not have been such a bad year. Paint sales, after all, did exceed $11 billion. Specifically, paint sales for 1991 totaled $11.4 billion, down 3% from $11.8 billion in 1990. As the industry reformulates coatings to satisfy environmental concerns, fewer gallons of paint may be produced, but more area may be covered. It is a classic case of doing more with less. In the case of paint, higher solids coatings cover more area per gallon while emitting fewer volatile organic compounds (VOCs). The discussion that starts on this page cites the salient statistics.

However, these statistics do not include data for thermal-spray coatings which are the subject of a discussion beginning on page 45. This small but growing technology has been around since the 1920s, but it is now gaining momentum. Improvements in equipment able to heat, melt, and discharge metals, ceramics, carbides, and even plastic materials allow thermal-spray operators to coat metal, wood, plastic, glass, or even paper with high-performance coatings. Although these thermal-spray coatings are not traditional polymer-type paints and coatings, they do provide unusual coatings that are unobtainable in any other way. Thermal-spray coatings can provide improved resistance to abrasion, corrosion, and weathering in a variety of high-technology applications from aircraft engines to bridge maintenance.

Meanwhile, in the more prosaic world of traditional polymer coatings, titanium dioxide shortages were a big concern just a few years ago. Today, with the addition of new plants and added-capacity facilities both in North America and around the world, the pigment is in plentiful supply. Beginning on page 64, titanium dioxide producers discuss the current market. Although prices may have moderated for the moment, at least one producer, SCM Chemicals, believes prices will have to increase in the future to pay for the new plants now in operation.

Inorganic color pigment producers have an entirely different concern. Although titanium dioxide has a clean bill of health, lead chromates and other heavy-metal pigments may be toxic. Industry suppliers argue that formulated pigments with reduced solubility pose little environmental hazard. In a discussion beginning on page 71, they point out that these pigments, used only in paints for industrial equipment, bridge maintenance, or marking traffic lanes, are cost effective and pose little danger to people. However, regulations pending at the Environmental Protection Agency under the Toxic Substances Control Act (TSCA) may ultimately drive the formulation of coatings with more organic pigments. Not only are environmental groups promoting a shift away from inorganic pigments, but some organic-pigment producers and paint-additive manufacturers are ready to step in with replacements.

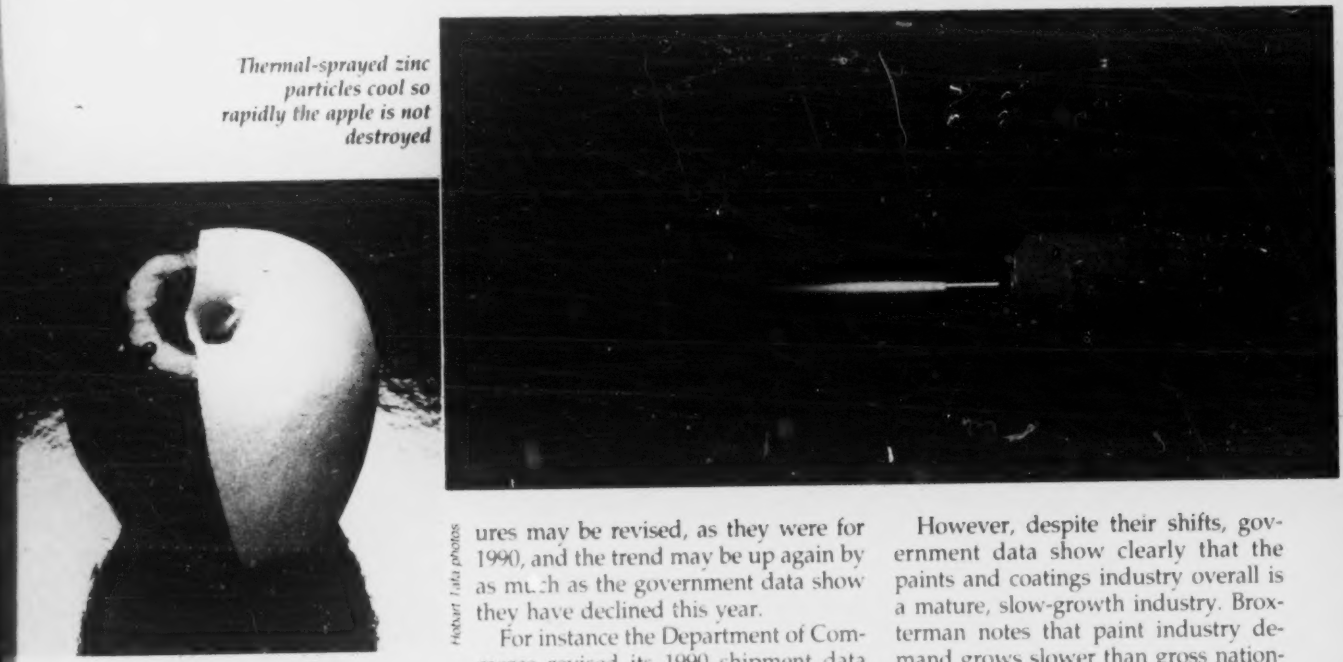
Shipments declined 5% last year

If industry statistics are taken at face value, the paint industry was deeply affected by the recession in 1991. The Department of Commerce reports that shipments declined almost 5% that year compared with 1990, to a little more than 1 billion gal.

But the statistics do not tell the full story. Under government pressure to lower levels of VOCs in their products, manufacturers continue to substitute coatings containing a higher percentage of solids. (VOCs are components in the formation of atmospheric smog.) Where practical, users have shifted away from traditional solvent-borne coatings to alternatives such as oven-cured powder coatings or radiation-cured low-VOC liquids.

In addition, the high cost of disposing of overspray captured in industrial settings has prodded users and manufacturers to more efficiently transfer paint or powder from spray gun or applicator to the area to be painted. As a result, coating efficiencies have increased to the point where fewer total gallons cover more area.

Thermal-sprayed zinc particles cool so rapidly the apple is not destroyed



Hobart Tafa photos

Thus, industry shipments may not be an absolute indicator of the health of the paint and coatings industry. Indeed, shipment declines may indicate the success the industry has had in doing more with less. According to Bill Broxterman, president of consulting firm ChemQuest, Cincinnati, statistical declines in gallons used do not account for the increase in solids per gallon, or the increasing use of 100% solids powder coatings. "If you were to measure actual coatings coverage on a dry weight basis, it is increasing," he explains.

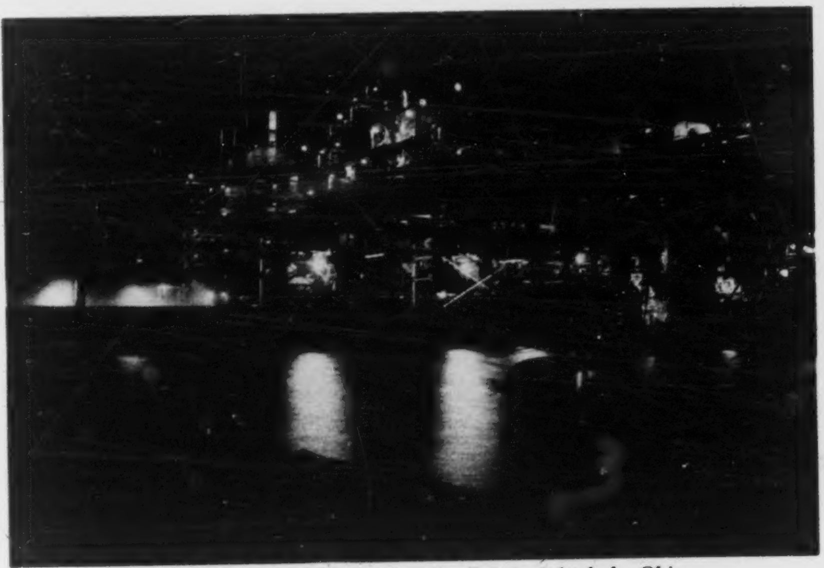
Transfer efficiency has also improved, notes Broxterman, thereby reducing actual volume used and giving the appearance of slower growth. About 20 years ago most industrially applied coatings were sprayed on but only about 20% of the spray actually coated the intended object. Increasing industry use of roller techniques to apply coating to metal coils (used for instance in manufacturing refrigerators, washers, and driers), helped to achieve a transfer efficiency of more than 95%, says Broxterman. Electrostatically applied powder coatings accomplish transfer efficiencies that exceed 90% because the overspray can be captured for reuse, he says.

Looking at the paint and coatings market in actual dollar terms, the value of industry shipments approached $11.4 billion in 1991. Although that may be an actual dollar decline of 3% from 1990, Commerce Department figures may be revised, as they were for 1990, and the trend may be up again by as much as the government data show they have declined this year.

For instance the Department of Commerce revised its 1990 shipment data upward nearly 10% from what it showed in its reports last year at this time. Similarly, it revised the value of those shipments upward by more than 1%. But what is important is that long term the actual number of gallons shipped between 1987, a year when the U.S. economy was strong, and 1991, when it was weak, has hardly increased—remaining at a little more than 1 billion gal. Similarly, the value of those shipments—up about 3% annually—has hardly increased considering the rate of inflation.

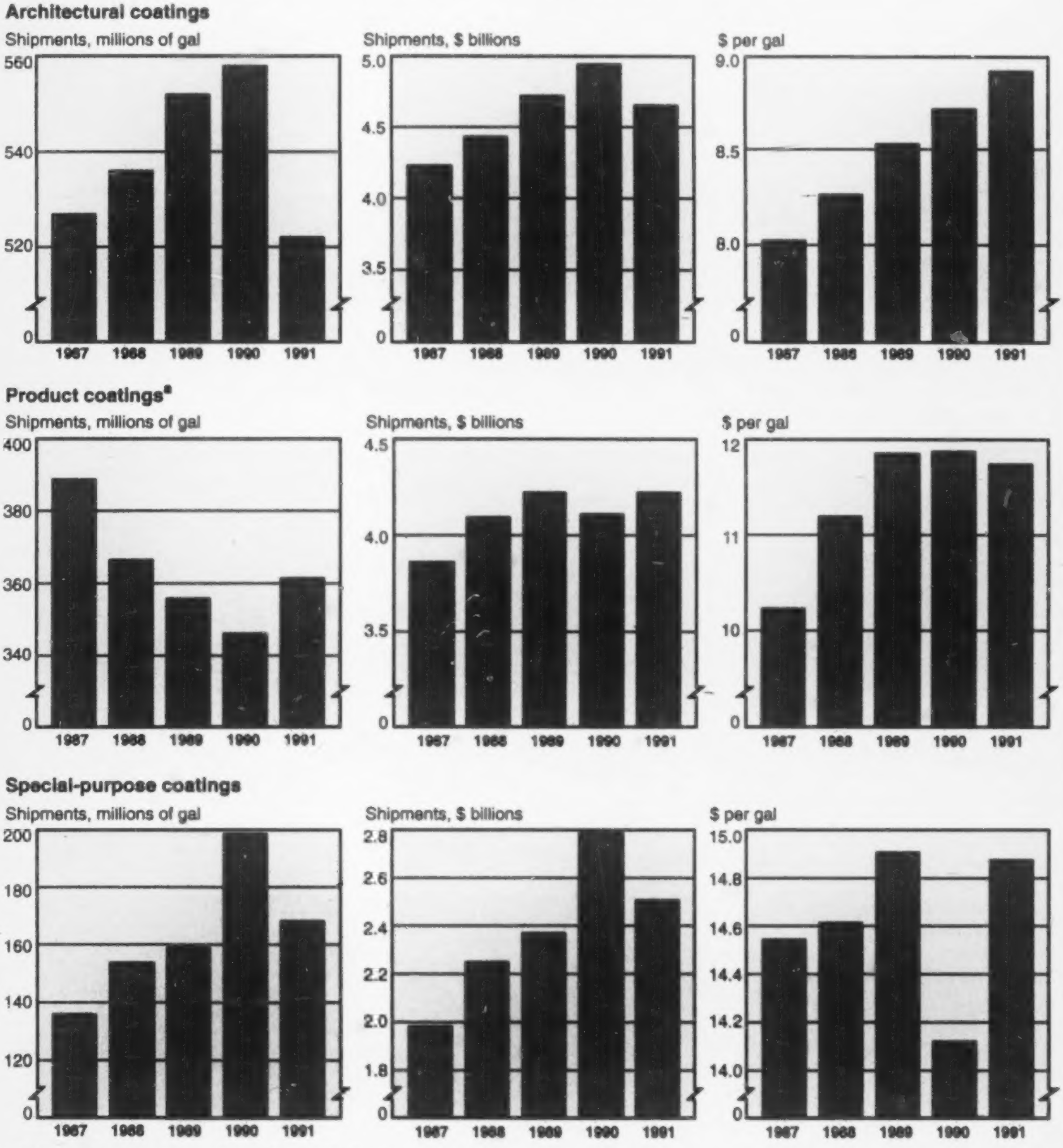
However, despite their shifts, government data show clearly that the paints and coatings industry overall is a mature, slow-growth industry. Broxterman notes that paint industry demand grows slower than gross national product. It is an industry in which opportunities present themselves to paint suppliers either as technology shifts to favor one supplier over another or as competitors attempt to increase market share. At the same time it is a besieged industry that must fund the development of alternative technologies as it comes under environmental and regulatory pressures.

New environmental regulations loom on the horizon, notes consultant Kline & Co.'s business manager of adhesives and coatings, Jeffrey Back. He



SCM Chemicals' titanium dioxide plant in Ashtabula, Ohio

Product coatings shipments rose, but others declined



a Original equipment manufacturers. Source: Bureau of the Census

warns that EPA will be promulgating regulations in the next 18 to 24 months that will affect hazardous chemical emissions and some paint chemicals, including isophorone, napthenol, toluene, ethylbenzene, methylchloroform, xylenes, and all the glycol ethers.

The industry paid for its continued reformulation efforts and the development of alternative technologies in part through increases in the average price charged per gallon of paint shipped. In 1991, the average price per gallon rose almost 2% to $10.84, compared with $10.68 in 1990 and with $10.58 in 1989.

The industry continued its reformulation efforts even with those modest price increases, in part because of lower raw materials costs during the current recession. Paint material prices declined marginally in 1991 compared with 1990, according to the latest data from the Department of Labor. For the first eight months of 1992, preliminary data show those costs have increased marginally.

Manufacturers have wrung additional savings through reductions in employment and concomitant increases in productivity. A look at the Department of Labor's paint and coating industry employment data shows that overall employment has been slipping since 1989. Although employment dropped about 2% in both 1989 and 1990, the decline accelerated in 1991 to over 5%, bringing total industry employment to 57,900. That is the lowest level in 10 years. The industry produced 193 million gal more of coatings in 1991 than in 1983, when nearly the same number of production employees, 29,500, worked in the industry.

Mergers and acquisitions also tend to reduce industry costs as larger producers are able to gain through manufacturing and distribution efficiencies. However, the pace of mergers and acquisitions has slowed over the past year. One major acquisition stands out—Rohm & Haas acquired Unocal's emulsion polymer business, including six U.S. plants and a technical center in Charlotte, N.C., for approximately $175 million. Rohm & Haas also strengthened its international position in acrylic emulsions by increasing its ownership of Japan Acrylic from 48% to 67%. The company did not disclose the cost of its increased holdings, purchased from partner Toagosei Chemical.

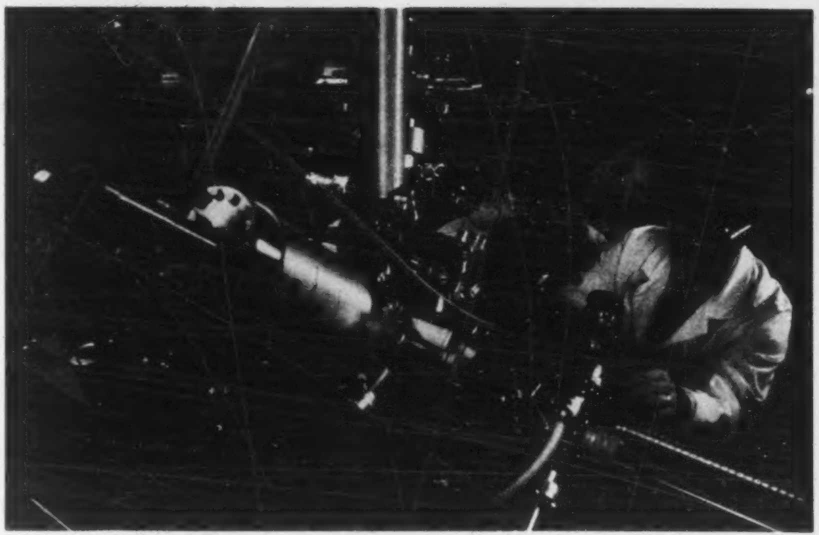
Rohm & Haas sees advantages to increasing its position in the emulsion polymers business, and a recent report from the Freedonia Group, Cleveland, may explain why. The report, "Paint Polymers & Chemicals," predicts that the paint chemical mix in the next few years will increasingly favor higher priced chemicals such as resins, pigments, and additives while demand for solvents, which tend to be lower in price, will continue to decline.

Total paint chemical demand, which Freedonia sets at just under 11 billion lb in 1991, will rise to nearly 12 billion lb by 1995. The total value of paint chemicals likely will rise from the present $5.7 billion to $7.2 billion in 1995. The study projects that the weight of chemicals per gallon of paint will drop from 10.4 lb in 1991 to 9.5 lb in 1995, largely because of the shift to water-borne coatings.

According to the study, the paint chemical category that will have the highest annual growth is organic pigments, whose use could increase nearly 10% annually to 55 million lb in 1995. The study notes that cadmium, chromium, and lead-based inorganic pigments are all under environmental scrutiny, though it projects their use will still grow about 4% annually to 320 million lb in 1995. A number of pigment suppliers have stopped supplying some inorganics, but organic counterparts are more expensive by a factor of three to five times "and generally perform less well," notes the Freedonia study.

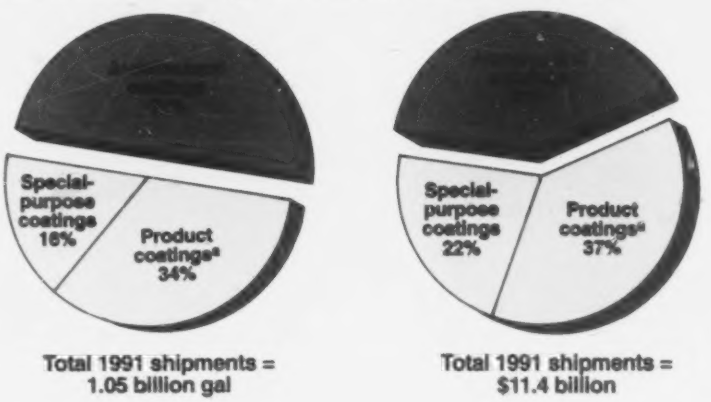
These paint chemicals are used in architectural coatings, which accounted for half of industry shipments in 1991; followed by product coatings, which accounted for a little more than a third of shipments; and special-purpose coatings, which made up the remaining 16% of total paint shipments. Shipments of architectural coatings in 1991, which include paints applied both to interior and exterior surfaces, declined more than 6% from the previous year to 522 million gal. The value of those shipments also declined about 4% to $4.65 billion. The unit price per gallon rose only a little more than 2% to $8.91. The recession continues to have a negative impact on these coatings markets. Whereas housing starts improved toward the latter part of the year, they still lagged previous years. This category still accounted for nearly half of industry shipments, and was little changed from the year earlier.

Shipments of product coatings, which consists of the original equipment market, last year rose a little more than 4% from the previous year to 361 million gal. The value of those shipments also



Scanning electron microscope is used to analyze surface structure of thermal-spray coatings at Air Products & Chemicals headquarters

Architectural coatings dominated business in 1991



a Original equipment manufacturers. Source: Bureau of the Census rose about 3% to $4.24 billion. Unit price per gallon however decreased 1% to $11.75. A good market for U.S. exports helped increase paint shipments to product manufacturers who subsequently exported finished products. As a result, the total value of product coatings rose compared with last year, but slow finished product demand on the domestic front kept product coatings unit prices under pressure.

Special-purpose coatings shipments declined nearly 15% from 1990, according to the government figures, to 168 million gal. The value of those shipments also declined more than 10% to $2.5 billion. However, unit prices increased 5% to $14.88, reflecting increased costs as paint makers reformulated their products to satisfy environmental regulations. A large measure of the reduction may be accounted for in the government sector. The length of the recession and its effects on municipal finances have in many cases forced municipalities to postpone maintenance on bridges and other outdoor structures.

Three main paint categories break down this way

ARCHITECTURAL COATINGS
- Exterior house paints
- Interior house paints
- Undercoaters, primers & sealers
- Stains

PRODUCT COATINGS[a]
- Wood furniture & fixtures
- Automotive
- Metal containers
- Machinery & equipment
- Factory-finished wood
- Metal furniture & fixtures
- Sheet, strip & coil
- Nonautomotive transportation
- Appliances
- Electrical insulation
- Marine
- Film, paper & foil
- Pipe
- Toys & sporting goods
- Miscellaneous consumer & industrial products

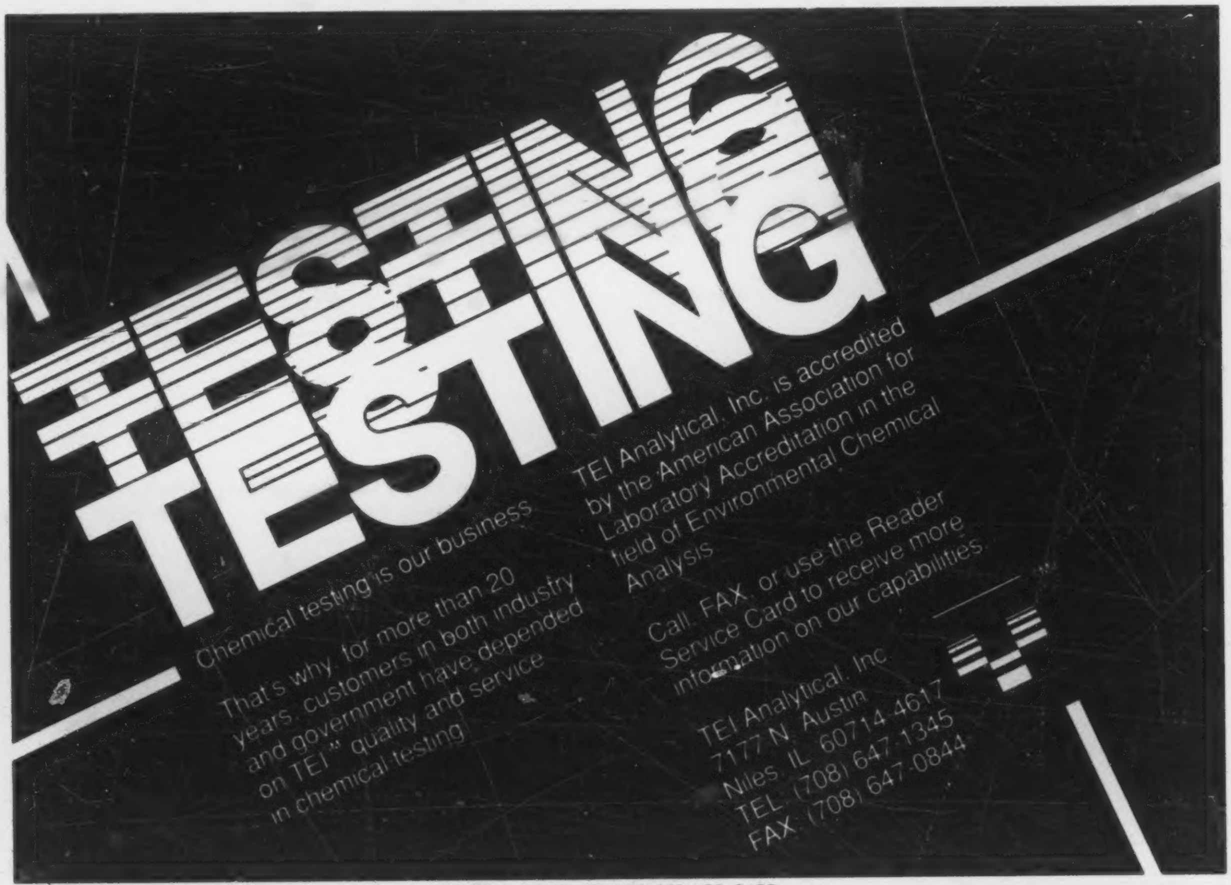
SPECIAL-PURPOSE COATINGS
- Automotive & machinery refinishing
- High-performance maintenance
- Traffic paint
- Roof coatings
- Bridge maintenance
- Aerosols
- Swimming pool coatings
- Arts & crafts
- Metallic coatings
- Multicolored coatings

[a] Original equipment manufacturers. **Source:** SRI International

Thermal-spray techniques impinge on traditional coatings markets

As the technology to apply thermal-spray coatings has improved, these metal, ceramic, and carbide materials promise to outperform traditional polymer paints and coatings. In rugged environments, they may outperform traditional bridge and industrial facility coatings. They may also provide surer footing on oil rig platforms or tanker trucks because they do not degrade rapidly under severe service conditions.

Thermal-spray applications of metals, ceramics, and carbides can also provide durable and rugged coatings where very few other coatings will sur-



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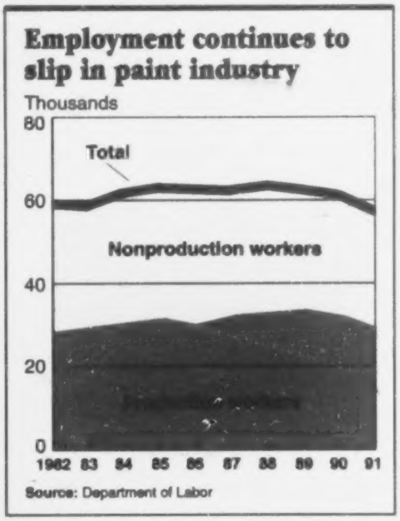


Employment continues to slip in paint industry

Source: Department of Labor

vive, such as in the high-temperature environment of an aircraft turbine engine, or on the walls of an industrial boiler. Thermal-spray carbide coatings can extend the life of industrial drill bits used for oil well drilling. New technology also makes it possible to thermally spray plastic materials onto metal substrates for outstanding salt and corrosion resistance on structural steel bridge components or in industrial maintenance settings.

Thermal spraying is itself a generic term for a number of coating processes that heat, melt, and propel metallic, ceramic, carbide, or plastic particles onto a substrate. The particles flatten upon impact and bond to the substrate. Thermal-spray coatings can be applied to a variety of materials including metals, oxides, ceramics, glass, plastics, wood, and even paper. Not all sprayable materials can be applied to all substrates. Thermal-spray processes include detonation, wire flame, powder flame, wire arc, high-velocity oxygen fuel (HVOF), plasma, and radio plasma.

Plasma-gun operators need eye and ear protection because of the bright light and heat these guns generate. Plasma-gun operators must also protect their skin from the intense ultraviolet light the guns produce. Cost of thermal-spray equipment ranges from $5000 for a simple flame spray gun to about $1 million for a computer-controlled plasma gun and spray-booth setup.

Thermal-sprayed coatings may be decorative when, for instance, they are applied over a metal sculpture. They can provide wear resistance, or reclaim worn or improperly machined parts in-place, such as huge industrial paper-mill rollers. Aerospace engine manufacturers use the coatings to create thin thermal barriers on turbine blades, thus raising the effective operating temperature of the engine and improving fuel efficiency.

Many of these high-technology applications exceed the capability of traditional coatings and might be labeled niche markets. Estimates on the size of the world market for thermally applied coatings, including equipment, materials, and job shop applications, range from well under $1 billion to over $2 billion. Estimates of the size of the U.S. market alone range from $500 million for materials, equipment, and job shop applications to just over $700 million.

Growth estimates for the thermal-spray coating industry run between 5 and 8% a year, though most insiders suggest that 1992 has been a slow year with little or no growth. Since aerospace applications make up close to 40% of thermal-spray coatings volume, the current military and commercial aerospace industry slowdown has certainly put a crimp on the growth

Paint materials demand to grow 1.1% annually through 1995

Millions of lb	1991	1995	% annual change 1991–95
Synthetic resins	2,420	2,830	4.0%
Alkyds	6,610	7,400	2.9
Acrylics	661	740	4.8
Vinyls	462	545	4.2
Epoxies	185	210	3.2
Other resins	462	550	4.5
Pigments	1,199	1,435	4.6
Titanium dioxide	889	1,060	4.5
Other inorganics	272	320	4.1
Organics	38	55	9.7
Solvents	5,014	4,736	−1.4
Additives	177	213	4.7
Minor paint chemicals	1,983	2,325	4.1
TOTAL	10,793	11,539	1.7%

Source: Freedonia Group

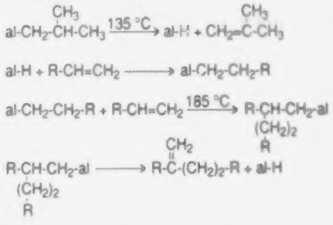
Alpha Olefins Answers

Roger C. Williamson, Ph.D.

Q: *I have an interest in olefins with a methylene group near the center of the molecule. Can these be prepared from your linear olefins?*

A: Our research determined optimum reaction conditions for this chemistry utilizing an aluminum alkyl (preferably tri-isobutyl aluminum) as a catalyst in an inert atmosphere. A temperature of 185-200 °C and an initial catalyst concentration of 0.5% gives reasonably fast reaction times of four to five hours. The conversion is limited to 55-65% due to the product competing with the starting alpha olefin for catalyst.

For simplicity, and since all aluminum alkyl bonds in tri-alkyl aluminums react the same, we abbreviate $Al\text{-}R_3$ to al-R in the following chemical reactions:



$$al\text{-}CH_2\text{-}\overset{CH_3}{\overset{|}{C}}H\text{-}CH_3 \xrightarrow{135\ ^\circ C} al\text{-}H + CH_2{=}\overset{CH_3}{\overset{|}{C}}\text{-}CH_3$$

$$al\text{-}H + R\text{-}CH{=}CH_2 \longrightarrow al\text{-}CH_2\text{-}CH_2\text{-}R$$

$$al\text{-}CH_2\text{-}CH_2\text{-}R + R\text{-}CH{=}CH_2 \xrightarrow{185\ ^\circ C} R\text{-}\underset{\underset{R}{|}}{\underset{(CH_2)_2}{\underset{|}{C}}}H\text{-}CH_2\text{-}al$$

$$R\text{-}\underset{\underset{R}{|}}{\underset{(CH_2)_2}{\underset{|}{C}}}H\text{-}CH_2\text{-}al \longrightarrow R\text{-}\overset{CH_2}{\overset{\|}{C}}\text{-}(CH_2)_2\text{-}R + al\text{-}H$$

A competing side reaction produces a linear internal olefin so the final reaction product consists of $R\text{-}\overset{CH_2}{\overset{\|}{C}}\text{-}(CH_2)_2\text{-}R$(90%)+R CH=CH-$(CH_2)_2$-R(10%). The reaction mixture is then cooled and washed with 25% NaOH. After drying, the mixture is distilled to recover starting olefin and the product as a bottoms.

Interestingly, the 1-tetradecene dimer (2-dodecyl-1 hexadecene) is a liquid at room temperature and undergoes most of the same chemical reactions as the linear alpha olefins.

If you have any questions about alpha olefins, please contact our Houston office.

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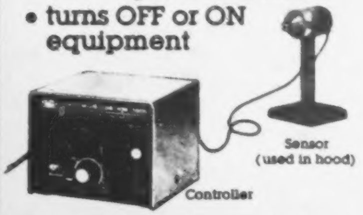

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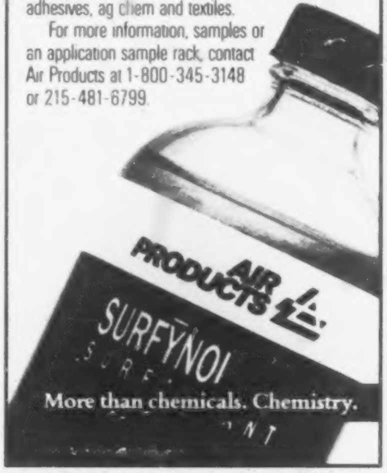

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of thermal-spray coatings. However, when the economy recovers, most industry observers see a market that will double in size in 10 years, particularly if Detroit automakers perfect and qualify thermal coatings for use in engine manufacture. In that event, industry observers believe the market could be $300 million, or in other words, as large as the aerospace market is now.

However, these thermal-spray market figures are dwarfed by the $11 billion U.S. market for traditional architectural, original equipment, and special-purpose polymer coatings. The industry is so small, the Department of Commerce does not even categorize it or collect separate data on it, say those who follow the thermal-spray industry. About all that is clear is that the U.S. does not include thermal-spray coatings in its definition of the paint and coatings industry, and so the data collected by the government do not include thermal-spray coatings industry information.

A major producer of thermal-spray equipment is Perkin-Elmer's Metco Division in Westbury, N.Y. It is among the largest equipment producers with about $123 million in annual sales, including sales of powder and wire. The Surface Technology Division of Swiss engineering company Sulzer has global revenues of $70 million annually for both thermal-spray equipment and powders. In the U.S., the company operates a thermal-powder supply business, Sulzer Plasma Technik, based in Troy, Mich., and an equipment supply unit, Electro Plasma, in Irvine, Calif., specializing in sophisticated plasma-spray units for aerospace engine manufacturers.

Another major player is Hobart Tafa, Concord, N.H. This company boasts that its sales will be $20 million this year from thermal-gun and spray-booth equipment, powder, and wire. Miller Thermal, formed by welding-equipment manufacturer Miller Electric in 1985, supplies powder from the former Alloys International plant of Baytown, Tex., and equipment from Appleton, Wis., with expertise derived from two companies it purchased: Metallizing Co. of America and Plasmadyne. Miller Thermal also has annual sales of about $20 million.

Praxair's Surface Technology, Indianapolis, is in a class all its own. It does not sell equipment, but manufactures equipment for its own use at 21 facilities worldwide. Praxair contracts with aerospace engine manufacturers or industrial maintenance units within the chemical process or oil exploration industry to coat parts to customer specifications with tungsten carbide, chromium carbide, and ceramics using its proprietary detonation gun. It has a separate ceramic-powder manufacturing operation from which it supplies powders to users of other types of thermal-spray equipment. Praxair does not break out sales for its thermal-spray-related businesses, but sources indicate annual sales may be about $200 million.

Other businesses involved in the thermal-spray market are independent wire and powder suppliers, such as Eutectic, a Flushing, N.Y., supplier of powders and elastomeric materials for thermal spray. Industry sources say that about 600 shops service customers, and that additional in-house maintenance users in the pulp and paper, glass mold, electric and gas utility, chemical, and petrochemical industries make use of thermal equipment for repairs.

Frank N. Longo of F. N. Longo Consultants, East Northport, N.Y., is a consultant on the thermal-spray market and writes a report, published by the Gorham Group in South Windham, Me., on the industry. Longo estimates the size of the North American market at between $600 million and $700 million per year. The figure includes equipment sales, powder, wire, contract coating services, and in-house maintenance users. The largest market now is for jet-engine manufacture, which Longo estimates is 40% of the market. Because of the successes jet-engine manufacturers have had in using thermal-spray coatings to provide thermal protection inside jet engines, the coatings are now being developed for stationary gas and steam turbines that may generate electric power.

Because of the overall slowdown in air travel (as well as the declining commercial and military purchases of airplanes) industry growth, normally running at about 7% a year, has slowed considerably, Longo notes. New markets now are developing for metal thermal coatings in industrial boilers to reduce or eliminate corrosion, he explains, but existing coatings systems have not come far enough along to ensure 100% coverage of boiler surfaces.

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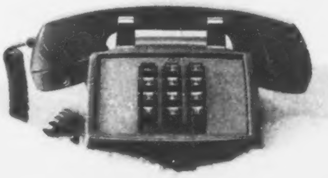

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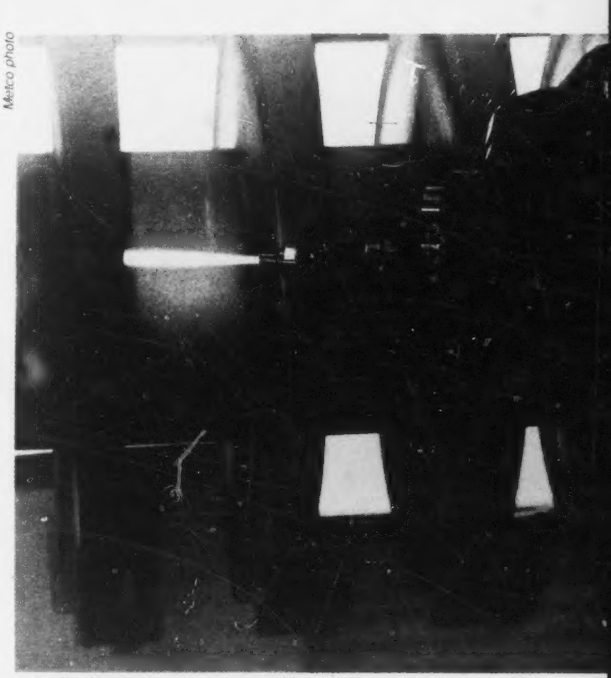


Metco photo

HVOF thermal-spray gun applies coating to metal screw used in waste disposal facility

He believes that use of recently developed HVOF-applied coatings can eventually succeed in this market.

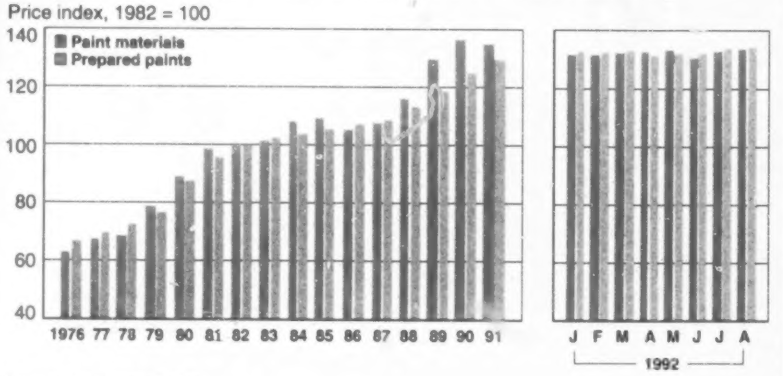
The most important developing market, he says, is in automotive gasoline and diesel engines to coat bearing surfaces and to reduce wear on engine cylinders. Detroit automakers already use metal arc-spray techniques to fill in autobody metal seams, but that is a relatively small market that one market manager pins at about $4 million per year. Other potentially large markets are the use of zinc and aluminum for bridge coatings. Europeans have used thermal coatings for at least 50 years to maintain bridge superstructures.

There is no doubt that for bridge or industrial facility maintenance, thermal-spray costs are much higher than those of traditional polymer applications. For instance, notes Merle Thorpe, president of Hobart Tafa, coating a bridge with traditional polymer applied coatings may cost $1.25 per sq ft including labor and equipment, but using a wire-flame spray coating of zinc may cost $5.00 to $6.00 per sq ft.

Robert H. Unger, vice president of Hobart Tafa, says conventional galvanizing provides only a thin coating that will protect steel from rust for two to three years in a corrosive environment. Application of paint over the galvanized steel may extend total life to eight years. Six mils (1 mil = 1/1000 inch, a measure of coating thickness) of zinc spray applied to the steel superstructure of a bridge might extend the bridge maintenance cycle to 25 years or longer. Thicker coatings would provide a longer cycle. He estimates that Europeans thermally spray more than 40 million lb of zinc annually for corrosion protection. But U.S. thermal-spray applicators use less than 2 million lb of zinc annually (and most of that is for a noncorrosion application—zinc is applied to polypropylene paper for the manufacture of electrical capacitors).

Unger says zinc may also be applied to concrete structures to provide cathodic protection of reinforced concrete bridge decks. About 8 mils of zinc applied with wire-arc spray guns and then wired to a source of current can prevent corrosion of the rebar steel in reinforced concrete, thereby preventing concrete spalling. He estimates the useful life of such a system at about 10 years and the cost at between $7.00 and $11 per sq ft of concrete surface, including preparation, application, and surface sealing.

Another developing thermal-coatings market is boiler-tube protection, particularly where high-sulfur coal may be used to fire the boiler. The relatively recent introduction of HVOF spray guns allows applicators to apply denser coatings onto industrial boilers, thereby preventing the penetration of corrosive liquids that can lift a coating and shorten the useful life of boiler tubes. Chromium-nickel coatings perform well in industrial boilers, notes Thorpe, and are applied to thicknesses of between 15 and 60 mils. Though the application may be prosaic, the cost can be high. Costs of thermal boiler coatings now range between $70 and $100 per sq ft, he says. Hobart Tafa has a joint-venture company with International Nickel to supply thermal-spray jobbers with a 45% chromium, 55% nickel wire to coat boiler tubes.



Prepared paint prices rise as those of materials slip

Source: Department of Labor

Costs can vary widely depending not only on the metal, ceramic, or oxide applied, but also on the process, notes Thorpe. Wire arc spray requires an electrical source and a compressed-air source. Wire flame and HVOF can use a mixture of oxygen with either propane, natural gas, hydrogen, or acetylene. Plasma guns require an inert gas such as argon or nitrogen with an admixture of either hydrogen or helium to increase heat content and velocity, and also require an electrical source to generate the plasma. Thorpe says that an HVOF gun his company recently introduced operates on lower cost kerosine as compared with more expensive fuels such as propane or acetylene.

Although zinc, aluminum, and other commodity metals may cost $1.00 to $2.00 per lb in a form suitable for thermal spray, other thermal-spray materials are more expensive. Tungsten carbide, for instance, may cost $20 per lb. Specialty alloys and composite materials may cost as much as $60 to $70 per lb, says consultant Longo, and some patented plastic specialty materials may be as much as $80 per lb. These material costs are certainly in excess of costs for traditional polymer-type coatings.

Because of the high costs of thermal-spray coatings, Kline & Co.'s Back believes that the success of thermal-spray coatings will be limited to niche applications. To expand thermal-spray coatings beyond the niche markets, proponents will have to persuade industrial and municipal customers that the higher costs provide greater benefits. For very costly applications, advocates will have to convince customers that no other alternative exists.

In the aerospace industry, thermal-spray coatings are often the only materials that allow a manufacturer to build a high-performance engine. General Electric research and development center staff scientist Paul A. Siemers says GE uses plasma-applied ceramic coatings as abradable thermal barriers for aircraft engine blade tip seals—a technology he says Metco pioneered. Electro Plasma, the Sulzer equipment manufacturer, helped develop plasma-spray coatings of metallic materials in low-pressure chambers to produce dense, corrosion-resistant coatings. The technology avoids having to oxidize the cobalt-chromium-aluminum-yttrium coatings that may be used on turbine blades.

Siemers says GE has looked closely at low-pressure thermal-spray systems because the company is exploring use of thermal-sprayed titanium, which is "very reactive in air." One possible use of thermal-spray titanium would allow the company to spray a titanium alloy on silicon carbide continuous filaments to make a metal matrix composite. The composite has double the strength and elastic modulus of titanium alone and may be developed for use in jet engines, he says. It is a high-cost technology; titanium-based powders can cost more than $150 per lb.

GE is looking into development of radio-frequency-generating plasma guns because it is interested in spraying titanium coatings, Siemers says. Conventional plasma guns have electrodes that may erode and contaminate the high-purity titanium. The radio-frequency plasma gun the company is developing requires only a 3-inch water-cooled quartz tube to generate the

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Varieties of thermal-spray equipment

WIRE FLAME OR POWDER SPRAY: A spark ignites an oxygen and fuel mixture, through which a metal or ceramic rod passes, or into which metal, ceramic, or carbide powders are introduced. A stream of air disintegrates molten material and propels it onto the workpiece. Gun designs differ depending on whether wire or powder is used, but in either case, only materials with melting points below 4500°F can be sprayed in this process. Wire may be sprayed at rates of 5 to 10 lb per hour, whereas powder rates are 1 to 20 lb per hour.

DETONATION GUN: The gun allows the introduction of oxygen and acetylene into a chamber containing suspended particles. A spark detonates the mixture eight times per second at temperatures that may reach 7000°F, propelling particles at supersonic velocity toward a workpiece. Praxair, which owns the gun design, custom applies coatings to customer specifications and does not license the technology to others. The gun fires round, wafer-shaped coatings of tungsten carbide, chromium carbide, ceramics, and chrome alloys.

WIRE-ARC SPRAY: Two wire electrodes feed into a gun to form an electric arc. Air, or an inert gas such as nitrogen, fed into the gun passes over the melting wires and propels droplets onto the target. Heat source temperatures can range between 4000 and 15,000°F. Deposition rate varies from 2 to 150 lb per hour for zinc.

HIGH-VELOCITY OXYGEN FUEL (HVOF): This gun allows the mixture of oxygen and fuel to achieve temperatures of about 5000°F. Metal, ceramic, or carbide particles exit at speeds approaching or exceeding those of the detonation gun, allowing for the deposition of dense coatings at application rates of up to 30 lb per hour.

PLASMA SPRAY: An inert gas passes through a direct current arc to superheat the gas into which metal, alloy, ceramic, and carbide powder may be introduced. Plasma temperature may exceed 30,000°F. Spray rates range from 1 to 25 lb per hour, depending on power input, which can vary from 14 to 80 kW.

RADIO-PLASMA SPRAY: An experimental process that uses radio frequencies to generate a gas plasma. The design eliminates electrodes that may erode in conventional plasma guns. General Electric is experimenting with designs, particularly for use in deposition of titanium.

radio frequencies in an inert gas atmosphere within the gun.

Another leading-edge aerospace application is use of tungsten-carbide-cobalt wear-resistant coatings over lightweight plastic composite materials such as carbon-carbon or carbon-epoxy helicopter blades, says Anthony J. Rotollco, engineering director for Metco. However, with the aerospace industry experiencing hard times, Metco and many other equipment suppliers are emphasizing the potential for growth in markets other than aerospace. Metco has perfected a rotating extension for its HVOF gun that allows the inside of an engine cylinder to be coated without having to physically rotate a cumbersome cylinder block. The cost-effective application of wear-resistant coatings to engine cylinders is something of a Holy Grail for the thermal-spray industry.

Another potential future market is in metal-plating replacements. Andrew B. Mazzone, operations director for Metco, points out that many metal-plating operations are under heavy regulatory pressure to reduce or eliminate disposal of spent plating baths. Plating companies can substantially reduce toxic disposals by use of thermal spray instead of plating. Using Hepa filters in controlled atmosphere spray booths would protect both applicators and the environment from metal overspray while substantially reducing disposal problems.

Rotollco also believes that use of glass bottles will increase in the future as plastics disposal problems increase. As a result, he sees Metco benefiting as glass manufacturers not only increase output, but also use more thermal-spray equipment to repair glass-molding equipment. Also under development at Metco is a program to apply ethylene acrylic copolymer plastic sprays to a variety of substrates in order to provide good weatherability and improve corrosion resistance.

Continued on page 62

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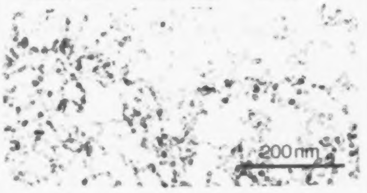

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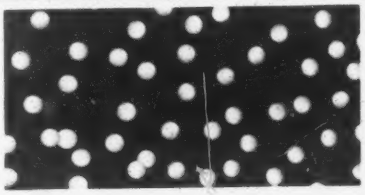

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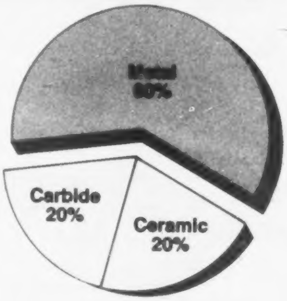
CIRCLE 30 ON READER SERVICE CARD

Continued from page 55

Because the plastics can be applied on site, they may well make durable coatings on bridges, lampposts, or even water towers for Food & Drug Administration-approved plastic color coatings. Tuck C. Nerz, a Metco materials engineer working with the plastic process, says deposit efficiency can be 85 to 90%.

Metco, notes Mazzone, is vertically integrated, manufacturing all its thermal-spray guns in-house. It also manufactures wire and powders to specifications for use in its equipment. Mazzone estimates wholesale costs to spray zinc coatings at $10 per sq ft. Boiler coatings could run at $40 per sq ft depending on the type of alloy used, and aerospace coatings could cost $150 per sq ft, also depending on coatings applied. The bulk of ceramic powders finds its way into the aircraft-engine manufacturing business now, he says, where it provides thermal-barrier coatings.

Metal powders are 60% of thermal-spray coatings



Total 1991 shipments = $130 million

Note: Data are for U.S. and exclude equipment. Does not cover materials for welding processes (plasma non-transferred arc and "puddle torch").
Source: Strategic Analysis Inc.

Jag Govind, a Silver Spring, Md.-based consultant, says that besides the ethylene acrylic copolymers Metco is developing for thermal sprays, nylons and a host of thermosets and elastomerics have been developed by other companies for thermal-spray coatings. However, he estimates that less than 50,000 lb of these materials, costing $6.00 to $10 per lb, are now applied versus about 145 million lb of more conventional electrostatic and fluidized-bed spray powder coatings.

However, Govind, who is working on a powder-coatings report for TPC Business Research Group, Lancaster, Pa., does see thermal-spray uses growing, and if natural-gas fuel for thermal guns can be developed, he sees a potential market for the process worth $200 million in two to three years. The thermal-spray plastics, says Govind, "are not likely to leave pinholes when applied," and as a result can "withstand corrosive environments and are ideal for in-situ applications." But despite their applicability in maintenance coatings, their high price makes them "unlikely to displace traditional polymeric coatings."

Thermal-spray materials supplier Eutectic provides elastomeric and thermoset materials as well as ceramic-metal powders, pure metals such as copper and aluminum, and carbides to service the glass-mold repair, maintenance, and machine-shop markets. The plastic materials must be used in thermal guns designed to accommodate them so that the material does not "burn up" before it reaches its target, says technical services engineer Frank D'Onofrio.

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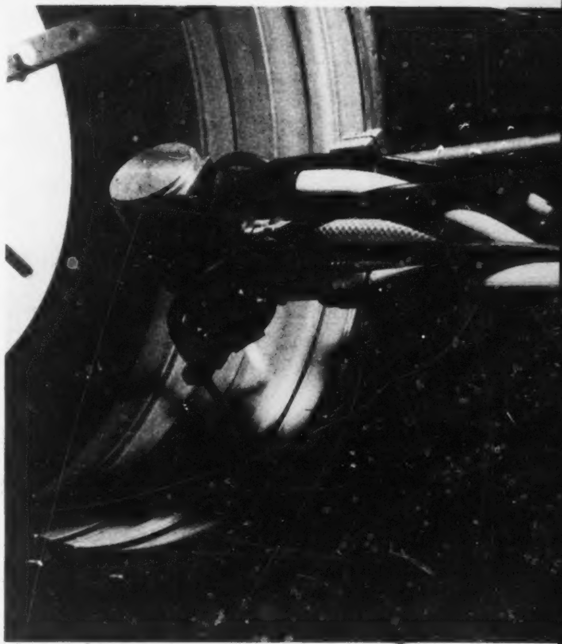
CIRCLE 31 ON READER SERVICE CARD

producer Sulzer Plasma Technik has been adversely affected by the current slowdown in the aerospace industry. "The slowdown has hurt, we all notice it," says the unit's president, John F. Seaman. Because of the drop off, Sulzer too is putting more effort into placing its materials in general industrial applications, he says. As a primary focus, Sulzer is concentrating on the market for coatings in stationary gas turbines used to generate power. Such high-temperature applications for thermal-spray-applied coatings is an area Sulzer knows best, says Seaman. The company is developing high-temperature-resistant gas turbine seals containing a polyester or polyimid combined with nickel, chromium, aluminum, or silicon powders for this market.

Charles P. Howe is communications manager for Miller Thermal, a company that manufactures a full line of thermal-spray equipment. One growing area is the use of plasma-spray equipment in the manufacture of medical implants, he says. In order for human tissue to adhere properly to medical implants such as stainless steel, titanium, or cobalt alloy bone and joint replacements, a coating must cover the implant. Plasma-applied hydroxyapatite forms a porous bioceramic that adheres well to the medical implant and also promotes good tissue adhesion, says Howe.

Howe believes industrial-related thermal-spray business will improve once business picks up in general. One area that will hold promise when the economy turns around is in rebuilding paper finishing rollers in situ with a metal facing that can be "superfinished" to a mirrorlike finish.



Metco plasma gun sprays clearance-control coating onto jet engine combustor liner

Besides Praxair, at least one other industrial gas supplier has more than a passing interest in thermal-spray coatings. Air Products & Chemicals not only supplies gases to thermal sprayers, it has set up a research lab devoted to solving problems affecting thermal sprayers. It has, for instance, developed a specialized propylene fuel it sells under the Apachi trademark to replace hydrogen frequently used in HVOF guns. The Apachi fuel is for applications "less demanding" than aerospace, says barrier-coating group manager Edward Hayduck.

Air Products also has developed two new arc-spray processes. One is for applying corrosion-resistant magnesium-containing coatings, the other is a titanium-nitride coating for wear and corrosion resistance to boilers, rollers, mixing blades, or even within process reactors. Hayduck says Air Products is talking to applicators in an effort to license the technology. The company currently refers to both processes by the Ceramarc trademark.

Titanium dioxide prices finally moderate

Steep price increases between 1987 and 1989 made it appear that the sky was the limit for titanium dioxide—the most widely used white pigment in the paint and coatings industry today. However, annual price increases moderated in 1990 and actually declined during 1991, according to Labor Department figures. A world recession and a number of new facilities coming on-line helped to put a crimp in price increases during the past two years.

Department of Labor figures show that producer prices for titanium dioxide rose at a compound annual rate of more than 10% between 1987 and 1989. However, prices rose a little more than 4% in 1990 from 1989 and actually declined nearly 3% in 1991. Prices have hardly changed during the first six months of this year. Although paint manufacturers may not exactly rejoice over the price situation, they must be heaving a collective sigh of relief. Titanium dioxide is, after all, a major ingredient in paints. Market sources report that U.S. paint producers consume more than 500,000 tons of the pigment annually, valued at more than $900 million.

This is a good time to be a pigment buyer in the coatings industry, says consultant Jim Fisher, president of International Business Management Consultants, Princeton, N.J. Pigment producers have come up with newer, higher performing grades of titanium dioxide, he continues. And because of the more than adequate supply situation, "it's a good time to make sure you have the right supplier and not just a fair-weather friend, particularly if you had a problem in the past getting adequate titanium dioxide supplies." The titanium dioxide business is a cyclical one, he emphasizes. When world economies speed up again, titanium dioxide supply will again be tight.

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Fisher says the early 1980s also saw low pigment prices after a period of expansion in the seventies. But during the eighties government regulations affecting effluent discharges forced a number of plant closures, including those of Tioxide in Billingham, U.K.; NL Industries in Sayerville, N.J.; Gulf & Western in Gloucester City, N.J.; and Dow Chemical in Balboa, Spain. Recent plant additions have reversed the situation. In North America alone, Du Pont, Tioxide, SCM, and Kronos (formerly known as NL Industries), have put into place new plants or expansions.

Titanium dioxide prices are still high—in the 90-cents-per-lb range—compared with what they were five or six years ago. Because of this, paint producers are still motivated to cut their use of titanium dioxide and use more extenders. Says Kline & Co.'s Steve Van Kouteren, many manufacturers have stuck with paint formulas that use more kaolin and calcium carbonate. If producers made the same number of gallons in 1992 as they did in 1988, "you'd see a slight decline in titanium dioxide demand," he says.

According to Jack D. Travis, national sales manager for Du Pont's white pigment and mineral products group, demand for titanium dioxide has increased 3 to 5% so far in 1992 compared with 1991. "This is apt to be a very slow recovery over a long time frame," he says, referring to improved prospects both for paint uses of titanium dioxide and the U.S. economy overall. There is indeed an oversupply now of titanium dioxide, he adds.

That is part of the reason Du Pont put into effect a "voluntary allowance" or discount of 2 cents per lb for titanium dioxide sold in the U.S. market between June 26 and Sept. 30. After September, "we will watch the market and determine if it is appropriate to remove or extend the allowance," says Travis. "Stay tuned," he adds.

Since Du Pont intends to be a titanium dioxide supplier long term, Travis says that service, reliability, and assured supply are some of the strengths Du Pont

SCM Chemicals photo

Titanium dioxide is the most widely used white pigment

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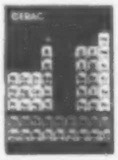

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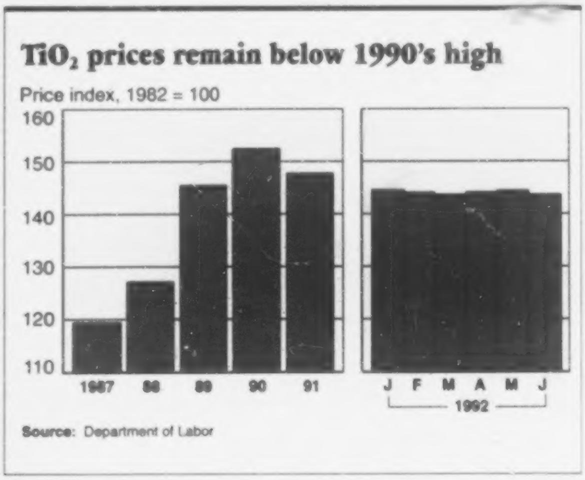

TiO$_2$ prices remain below 1990's high

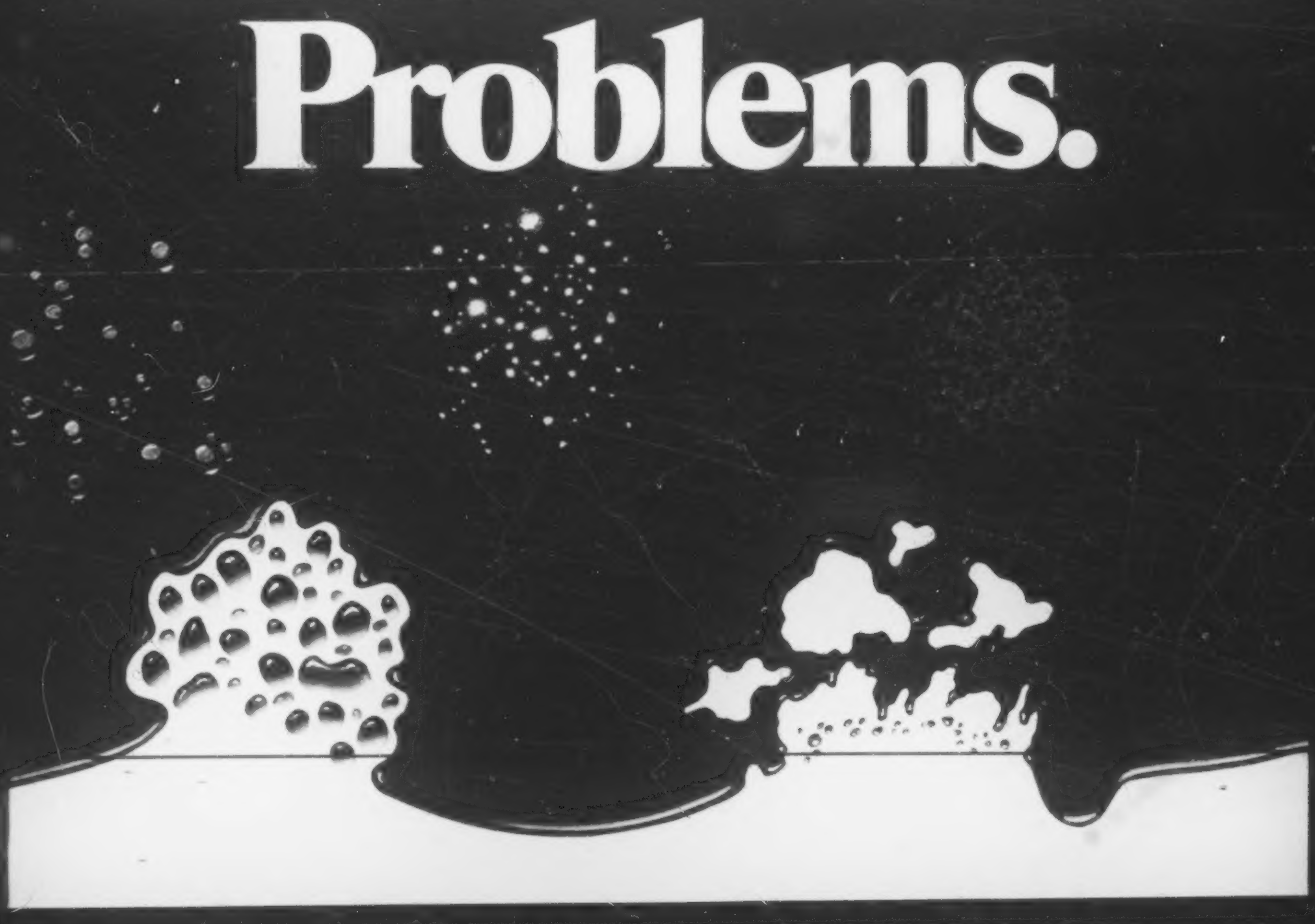
Source: Department of Labor

brings to its customers. Within the last year it has also introduced new titanium dioxide pigments—R700 for good dispersion in interior latex paint, and R702, a white pigment for use in durable exterior architectural enamel and industrial finishes.

Donald V. Borst, chairman, president and chief executive officer of SCM Chemicals, says his company has just opened a new 53,000-metric-ton-per-year titanium dioxide plant in Ashtabula, Ohio. Product is "selling strong," and the company is "getting a competitive price" for it. He believes that "we are at the bottom of the titanium dioxide cycle now," and hopes that when Du Pont's voluntary "allowance" ends in September, the price of titanium dioxide will rise a bit. "We need the increase," he says, to pay both for environmental costs and recovery of losses due to inflation. Recently, SCM introduced RCL 535, a new grade of titanium dioxide for coatings with good durability and gloss.

Louis R. Griffis, operations support manager for Kerr-McGee's pigment division, says titanium dioxide is a profitable product "even in these hard times." Kerr-McGee's "level of service has always been pretty high. ... We meet competitors' prices and have increased our market share." The company, which until recently had only U.S. operations, now has a joint venture operating a titanium dioxide plant in Australia, and an equity position in a plant in Saudi Arabia, making the company more of a global player, according to Griffis. Last October the company introduced CR 828, a universal titanium dioxide grade that gives customers more formulating "options" with a single grade, he says.

Engelhard's David E. Gregg, specialty kaolin products marketing manager, points out that though titanium dioxide supply is plentiful now, the company has seen no drop in demand for kaolin used as a titanium dioxide extender. "Earlier titanium dioxide shortages taught paint makers the use of extend-



ers." Paint manufacturers who established a paint formula when titanium dioxide supplies were tight have no reason to reformulate now that supplies are more available, he says.

Pigment producers anticipate heavy-metal concerns

Whereas titanium dioxide producers are wrestling with excess capacity and are less occupied with environmental concerns for the moment, the situation is reversed for inorganic pigment producers. Pigment producers are not complaining about excess capacity, but they are worried about the potential impact any regulations might eventually have on inorganic pigments, such as lead chromates.

These pigments are not used in any consumer-applied paints. Instead they are still used in many industrial maintenance coatings for their excellent color retention and durability under severe conditions. Jay Willner, president of WEH Corp., a consulting firm in San Francisco, says the U.S. market for industrial coatings high-performance pigments, including those used for petrochemical and waste treatment facilities, is about $250 million annually.

According to the Dry Color Manufacturers Association (DCMA), about 36 million lb of lead chromate pigment was used in paints in 1989. Other pigments that could be of concern because they too are considered heavy-metals pigments include strontium, mercury, cadmium, and zinc. One market source estimates the value of the heavy-metal industrial pigment market at $30 million annually, excluding titanium dioxide (which, incidentally, has a clean bill of health).

Miller Thermal photo

Zinc-aluminum coating is applied to naval vessel hatch for corrosion protection

In a 1991 filing with EPA to comment on pending TSCA regulations, DCMA said that lead chromate pigments are used in traffic striping paints for highways and airports, and in safety identification paints on buses, ambulances, and fire trucks. The group also says that soluble lead levels in these pigments are low enough that they pose little hazard

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to the environment, and do not at all pose the same threat as did highly soluble lead oxide pigments that were banned a number of years ago.

EPA is moving slowly on any rule making that would affect use of lead chromate pigments in the few areas now allowed. This is an election year, and the President has postponed rule making ostensibly to give businesses some regulatory relief during the current economic slowdown. But the pressure is not off paint makers and formulators.

Environmental groups are concerned about the presence of lead in the environment in any form. "All uses of lead should be phased out as a general matter," states Erik Olson, a senior attorney with the Natural Resources Defense Council (NRDC) in Washington, D.C. Although NRDC supports interim steps toward a complete phase out, Olson believes that ultimately there should be no acceptable exposure level to lead.

Fred Millar, director of the toxics project for Friends of the Earth, another Washington, D.C.-based group, says "there is no excuse for putting more lead in the environment. . . . It's as stupid a thing as I can imagine." Millar contends that substitutes for lead chromate pigments are available, and that formulators should immediately "get on with" not using lead in paints.

Burt Slutsky, market manager for Chicago-based lead chromate producer National Chemical, says few if any nonchromate pigments work as well as the lead chromates. "You pay more and get poorer performance," he claims. But he is aware of the movement toward lead-free products, and explains that lead chromate pigment manufacturers are either replacing their lines, putting off the replacement if they can, or getting out of the lead chromate business. Still, rumors of lead chromates' demise are "greatly exaggerated. It is still heavily used."

Currently, lead chromates are most heavily used in traffic paints—more than half of the lead chromates sold in 1989 were for yellow traffic-marking paints, according to DCMA. National Chemical is exploring lead chromate free replacements for this market, fully aware that some states, Virginia for example, now require lead-free traffic paints and others, such as Minnesota, plan soon to be lead free. In response to demand for lead-free pigments, National Chemical recently introduced a white pigment, strontium phosphate, for use in metal coatings.

David Waldron, vice president and sales manager of Cookson Pigments, Newark, N.J., says people have many misconceptions about lead chromates. Not all lead chromates are created equal. Cookson's silica-encapsulated lead chromates can meet state regulations concerning limits on soluble lead in coatings. "The hazard is soluble lead. It is not a problem if it is not soluble," explains Waldron.

The problem is that people presuppose that all lead is hazardous, Waldron continues. Doctors often require patients to consume quantities of a heavy metal, barium, in the form of barium sulfate in order to take digestive-tract x-rays. This form of barium is not soluble and may be ingested without deadly results, he says. However, if a person ingested a similar quantity of barium chloride, the person would die.

Waldron says that Cookson has engineered its products to have low lead solubility in response to market demand. "We believe the hazard should be controlled, not the ingredient." And he adds that replacement costs for lead chromates are "enormous"—as much as 10 times the cost of lead chromates. "We've discontinued the most soluble of our lead pigments," he says, among them strontium chromates. Cookson also manufactures organic pigments that are not under the same scrutiny as lead-containing pigments. The company recently invested $15 million to build capacity for new organic red pigments—quinacridone, pyroline, and anthraquinone. (Cadmium red pigments, which they replace, are considered to be a health hazard.)

SCM's Borst says his company has perfected a cadmium-selenium pigment that is "low leaching." Cadmium pigments, he admits, have higher temperature and better color retention properties than the cadmium-selenium pigments. However, the cadmium-selenium pigments have been in good demand since their introduction two years ago, he notes.

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CIRCLE 17 ON READER SERVICE CARD

Engelhard says that as it loses markets for cadmium pigments, it too is shifting toward replacement pigments. Craig J. Stoneback, specialty minerals and colors marketing director, explains that the company is marketing calcined inorganic pigments such as cobalts, titanates, or zirconates under the Meteor or Meteor Plus tradename. Although these pigments are opaque and durable under exposure to light, they do not have the color brilliance of lead- and chromium-containing pigments, he says. In some instances, the calcined inorganics may be offered in blends with heavy-metal pigments, but, cautions Stoneback, that is not happening now.

Donald P. Miller, trade sales colorants marketing director for Hüls America, says the company has offered heavy-metal replacements for lead chromates for 10 to 15 years, but they are five times more expensive. Users, he notes, are reluctant to "go lead free" unless they are told to do so. He says, "We would like to get rid of them in our plants even though they are a small part of our overall business." One barrier to conversion to lead-free pigments is that state governments are heavy users of those pigments in traffic paints. Miller points out that especially during these fiscally difficult times, governments do not want to spend the extra money for organic yellow traffic paints.

Harcross Pigments, until recently a part of Pfizer, manufactures iron oxide pigments that can partly substitute for lead chromate and other heavy-metal pigments. According to marketing manager John F. O'Neil, an entirely organic yellow for traffic paints will be more expensive, will not perform as well, and will not have the same lightfastness as the lead chromates. Without regulations in place, "most of the world would use lead pigments," he concludes.

According to Peter A. Lewis, coatings industry manager for the Sun Chemical colors group, monoaryl yellow may be as durable a traffic-paint pigment as heavy-metal-containing coatings. He does acknowledge that monoaryl yellow is eight times more expensive than lead chromate, but he says paint producers would need only 6 million lb of monoaryl yellow to replace 40 million lb of lead chromates. Sun, he says, manufactures only organic pigments. "Our customers are coming to us for advice on how to formulate away from lead," he says. Sun Chemical produces pigments such as naphthol red, quinacridone red, phthalocyanine blue, and arylide yellow.

"We are benefiting from the move away from heavy-metal pigments," says Rick Campbell, U.S. pigments general manager of organic pigments producer Hoechst Celanese. He decries the notion that heavy-metal pigments perform better than organics. "In our opinion, organic pigments are more light-fast than lead chromates, depending on customer requirements." Lightfastness is really not an issue, he says. He does admit, though, that organic pigments are sometimes significantly higher in cost and applicators may sometimes have difficulty fully hiding an undercoat if they apply a thin top coat film containing only organic pigments. Hoechst Celanese produces pigments such as naphthol reds, diarylide and hansa yellow, carbazole violet, and special azo pigments.

In an interesting twist, Ciba-Geigy has introduced an organic paint additive that it says can replace zinc, lead, or strontium chromate pigments for metal-corrosion protection in paint primer coatings. Tests of the additives have shown they are not mutagenic, according to Ciba-Geigy material safety data sheets, but may produce skin and eye irritation.

Ciba-Geigy is itself a producer of heavy-metal-containing pigments and metal-replacement chemicals. It offers those replacements in two forms based on (2-benzothiazolylthio)-succinic acid. The first, Irgacor 252, is a free acid form, whereas the second, Irgacor 153, is a liquid hydrophobic amine salt. The Irgacors are priced at parity with the heavy-metal systems they are meant to replace, says Tim Geran, coating additives technical representative. Geran adds that although the pricing of the product is meant to offer paint manufacturers an incentive to replace the heavy metals, government regulation will probably provide the best incentive for substitution. ☐

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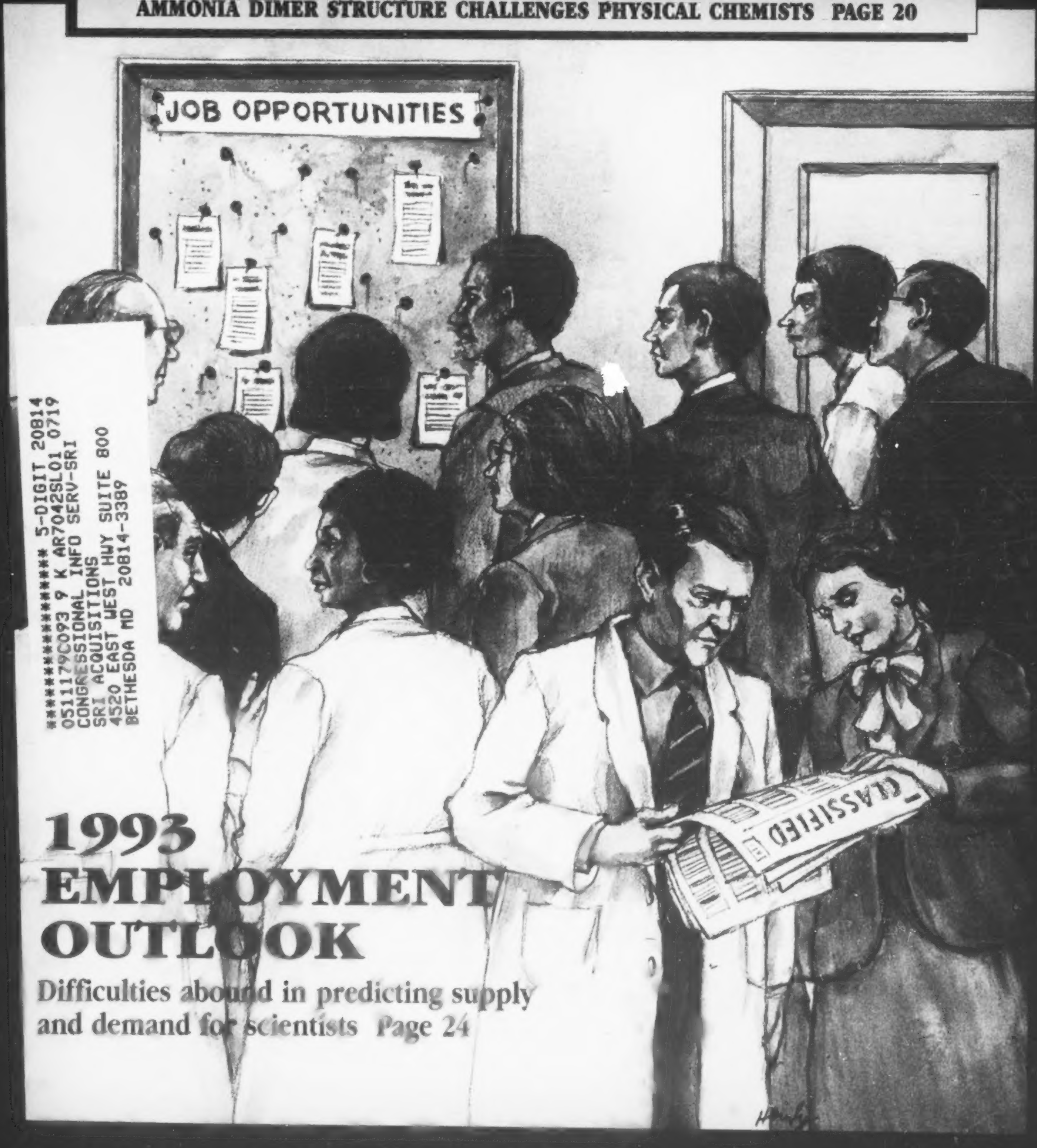
OCTOBER 19, 1992

AMMONIA DIMER STRUCTURE CHALLENGES PHYSICAL CHEMISTS PAGE 20



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CHEMICAL & ENGINEERING NEWS

C&EN

OCTOBER 19, 1992

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- Chemist Rudy Marcus has won the Nobel Prize in Chemistry; biochemists Edmond Fischer and Edwin Krebs have been awarded the Nobel-Prize in Physiology or Medicine. **Page 6**
- The U.S. has reached an $11.6 million settlement with Chemical Waste Management in the largest claim ever obtained for environmental crimes prosecuted under Superfund. **Page 7**
- Quantum Chemical has charged engineering firm M. W. Kellogg with fraud and negligence in the design and construction of Quantum's new ethylene cracker. **Page 7**
- NASA proposes to shut down two satellites that carry instruments to monitor ozone depletion and global climate. **Page 8**
- Two chemicals widely used in the manufacture of semiconductor chips may significantly increase the risk of miscarriage, a preliminary study finds. **Page 8**

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Published by
AMERICAN CHEMICAL SOCIETY
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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Basic science for the future

Today there is grave cause for concern about future support for truly basic research. For some years in the U.K. and to an increasingly worrisome degree in the U.S., there is a rising tide of opinion among science policymakers that scientific research should be entirely targeted to goals that will increase our prosperity and (to employ the reigning buzzwords) our international competitiveness. Overzealous and ill-considered pursuit of these intrinsically worthy goals can seriously damage our capacity to achieve those very goals.

Let it be clearly acknowledged at the outset that the reason scientists, technologists, and engineers are supported from the public treasury is because the public expects to benefit from their work. There is nothing wrong with that implicit contract. It is a meritorious example of enlightened selfishness on the part of the citizenry, few of whom are themselves scientists or engineers, but all of whom enjoy the fruits of the labors of scientists and engineers in the form of safer, more comfortable, healthier, more fulfilling, longer lives.

The question is not whether, but how public support of research can be used more effectively. What are the essential components of a strategy that can meet all of our needs—both short term and long term?

First, it is easy to understand that in a modern industrial society many technical problems exist, and that it is appropriate to dispense research grants and contracts to those scientists and engineers who are proven (by peer review, preferably) to have the competence to deal with these technical problems and who desire to do so. For engineers, this is essentially the whole picture, because engineering is by definition the application of scientific knowledge to the practical needs of society. Engineers exist to achieve designated practical ends, and, therefore, that part of our research support system that funds people who work toward predefined goals serves the needs of engineers admirably. It also admirably serves the interests of the citizenry who pay for it.

Many scientists also find themselves very well accommodated by a research support system that deals with predefined problems requiring scientific study. These people are the applied scientists. For the most part they are employed in industry or in the laboratories of task-oriented government agencies. The fact that these scientists do applied research does not preclude the possibility that their work may turn up some new fundamental facts or concepts that have purely intellectual as opposed to (or in addition to) practical validity. But that is not their purpose, and if they are funded to solve practical problems their success should be measured by how well they do so. There are also applied scientists and engineers in universities and it is entirely appropriate—indeed absolutely necessary—that this be so.

However, there is another group of scientists whose place in universities (and in our overall scientific effort) is also both appropriate and necessary. These are the scientists who do what some call basic research or pure research. I dislike both of these terms because they are overloaded with ambiguity and snobbishness. I would prefer the term curiosity-driven research. In other words, there is research undertaken solely to answer questions concerning the still-unexplored aspects of the world around us without any predetermined use or application for the results that will be obtained.

Curiosity-driven research is an indispensable part of a complete national research strategy and is as fully deserving of support from the citizenry as research in engineering and applied science. Why? Because the applied science of the future will simply wind down in ever-decreasing circles to sterility without new and unanticipated increments to fundamental knowledge. Applied research cannot for long simply feed on itself; new facts and new concepts are what underlie real progress as opposed to a chain of ever-smaller incremental improvements.

Let us consider some examples. I'll choose only three; there are many more.

- We will begin with the use of x-rays to determine the structure of matter. Most of the practical successes in materials science today, as well as our understanding of genetics and enzymes would never have happened if physicists such as Max von Laue had not studied the interactions of x-rays with matter—just because they were curious.
- The studies by Lord Rutherford, and others, of the fundamental nature of atomic nuclei ultimately led to the use of

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New Graduates Face Tight Job Market

JOB OPPORTUNITIES

DEMAND

October marks the beginning of the recruiting season for companies hoping to hire next spring's crop of new chemistry and chemical engineering graduates. And, although there's always some uncertainty this early in the season, the year that's just beginning isn't shaping up to be a good one to be entering the job market with a new degree in these fields.

The general economic recession that made last year perhaps the worst in a decade to be entering the job market lingers on. Some employers of chemical professionals—such as makers of consumer products and pharmaceuticals—are fairly resistant to economic downturn, and at some of these firms demand for new professional staff remains high. But chemical and petroleum companies, whose demand for newly graduated chemists and chemical engineers makes the difference between a good year to be job hunting and a bad one, are very sensitive to conditions in the overall economy. With no clear economic turnaround in sight, many of these firms will be very cautious in their hiring in 1993.

C&EN tracks the volume of "positions open" advertising carried on its pages. It's an indicator of changes in demand for chemical professionals that has accurately reflected demand in recent years. The most recent "high" was an extended one that lasted through much of 1987 and 1988. Advertisements for positions to be filled started falling off about the end of 1988 and drifted downward, though far from steadily, well into 1991. Since then, the graph's been bumping along, up for a month or two and then down again, sending out signals that it might be ready to turn around, but never quite doing so.

That jagged line pretty much sums up the employment picture for this year's graduates. Much like the overall economy, chemical professional employment seems to be stuck in a recession that it can't quite get out of.

Certainly last year was not a good year to be looking for a first job in chemistry or chemical engineering. It wasn't a good year for midcareer chemical professionals, either, as major chemical and petroleum companies cut their expenses by, among other measures, reducing the size of their professional staffs.

For some companies, and on some campuses, the employment outlook for 1993 appears to be somewhat better. But even that modest claim isn't likely to be a universal one. Other schools and other companies predict that the coming year will be a repeat of last year or, perhaps, even worse.

Cautious, deliberate recruiting characterizes this year's efforts on the part of many chemical companies, suggests James D. Burke, manager of research recruiting and university relations at Rohm & Haas. "Companies will worry more about overhiring than underhiring," Burke says, at a time when the economy seems to be moving somewhat awkwardly toward recovery. "Now that we've all had a pretty good year, we're more willing to go out and invest in our future" by hiring professional staff, he says. He's predicting that recruitment efforts may start out slowly in the first half of the year but pick up in May or June if company profits do likewise.

At Du Pont, the outlook for 1993 recruitment is a little better than last year. For a year and a half, Du Pont has been in the midst of a program to cut its operating costs that has included reducing the size of its work force. Although that program will continue into next year, most of the staff reductions have already occurred, and its biggest impact on recruiting took place last year.

During the 1992 recruiting year, which ended last month, Du Pont hired about 175 chemists and chemical engineers at all degree levels, estimates Richard T. Koffenberger, a senior college relations supervisor. That's down substantially from hiring levels of two or three years ago. In fact, the company did not recruit on campuses at all last fall, although it did make some campus visits during the winter. Essentially all the hiring that occurred was of people who had prior experience with Du Pont through co-op programs, for example, or summer internships.

This year Koffenberger estimates Du Pont's hiring will be up by perhaps a third. That's partly because the cost reduction programs have been effective in improving the company's profitability and partly because some sectors of its business have held up fairly strongly. But another important reason, he says, is that "we recognize the value and need to continually bring in new professional staff who understand the workplace of today." In this regard, he says, "we have considerable pent-up demand for people." That demand will be tempered by an obligation to current employees, who are being considered first to fill available positions whenever their skills match those needed.

As is generally the case, Du Pont's principal needs will be for chemical engineers and Ph.D. physical scientists. "We have an increasing need for analytical chemists, at both the doctoral level and other levels," Koffenberger says. He expects demand will be up for polymer chemists, too.

Again this year, prior experience

with Du Pont will be a big plus in getting an offer of a full-time job. Du Pont will be recruiting on campuses this fall, but at a smaller number of schools than the company used to visit. It also will be recruiting through the employment clearinghouses of professional organizations, such as the American Chemical Society. Faculty contacts on many campuses, who bring promising students to the company's attention, and résumés mailed in by job seekers will also provide avenues for landing a job.

Supply of Ph.D. chemists alone is rising

Academic year	Degrees awarded in chemistry			Degrees awarded in chemical engineering		
	Bachelor's	Master's	Ph.D.	Bachelor's	Master's	Ph.D.
1979–80	11,446	1733	1551	6383	1271	284
1980–81	11,347	1654	1622	6527	1267	300
1981–82	11,062	1751	1722	6740	1285	311
1982–83	10,746	1604	1746	7145	1304	319
1983–84	10,704	1667	1744	7475	1514	330
1984–85	10,482	1719	1789	7146	1544	418
1985–86	10,116	1754	1908	5877	1361	446
1986–87	9,661	1738	1976	4983	1184	497
1987–88	9,052	1708	1995	3917	1088	579
1988–89	8,654	1785	2034	3684	1097	599
1989–90	8,126	1696	2183	3450	1030	564

Source: National Center for Education Statistics

Monsanto, too, will be on campus recruiting this year, though it's looking for only about half the number of inexperienced chemists and chemical engineers it used to hire in a "typical" year. That puts hiring of new graduates at around 50, just about the same level as last year, says Robert J. Mason, corporate director of university relations. That level is enough to replace professional staff who leave because of retirement and other factors and to provide for slight staff growth. In addition, Monsanto will be doing "quite a bit of hiring in the experienced ranks," Mason says. The reason: More employees than anticipated took advantage of the company's early retirement incentives offered last year.

Dow, on the other hand, will be hiring many fewer chemical professionals this year than last, according to James E. Townsend, manager of university relations for Dow Chemical USA. Townsend expects the company will hire about 40 chemists and chemical engineers this year, half of them probably Ph.D.s. That's about half the number Dow hired last year and one fourth the number it has been used to hiring. As a result, campus recruiting will be very limited. Almost all bachelor's- and master's-level hiring will be of people who've already worked for Dow as part of a co-op or internship program. Part of the reason college hiring will be so low, Townsend says, is that, unlike Du Pont and Monsanto, Dow has not cut its midcareer professional staff.

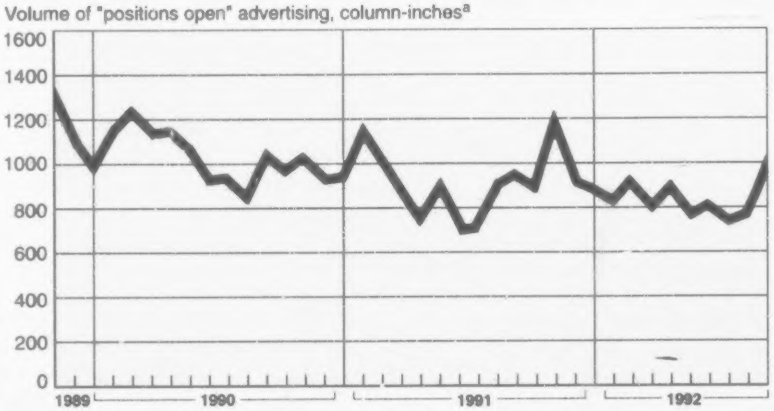
The companies in the best position to hire new chemists and chemical engineers this year are those outside the chemical and petroleum industries, says Ted J. Logan, manager of technical recruiting at Procter & Gamble. In addition to his own company, Logan cites other consumer products companies and drug firms as good places to look for a job. "Our products are in demand even in a recession," he points out. Procter & Gamble has a high demand for engineers and Ph.D. scientists this year and did so last year as well, Logan says. Though the outlook for new chemistry Ph.D.s in general is gloomy this year, demand is considerably stronger for Ph.D.s with degrees in analytical or synthetic organic chemistry, he says, because of demand from outside the oil and chemical industries.

Ph.D. chemists would be wise to look beyond the chemical and petroleum industries for the best job opportunities this year, agrees Rebecca J. Simon, placement director for the school of chemical sciences at the University of Illinois. Given the downsizing that's been taking place at many chemical and petroleum companies as well as general economic conditions, Ph.D. candidates last year didn't have as many choices as they are used to. This year, she says, employers seem to have their fingers crossed, hoping to hire a few more chemists and chemical engineers than they did last year. But that pickup likely will be more at the bachelor's and master's level than for Ph.D.s, she suggests.

Merck will be hiring chemical and other scientific professionals at about the same level as last year, says Anthony D. Rizello, manager of college relations. Although profits are strong, the company is being cautious about short-term staffing and only hiring to fill vacancies caused by attrition. Merck is looking to hire about 100 scientists this year, with an emphasis on chemists, and about 150 engineers in all areas, Rizello says. That's only about 40% of the number of new graduates Merck was hiring each year in the late 1980s. "We're primarily trying to maintain a certain size professional staff," Rizzello says.

At Phillips Petroleum, the view is much gloomier. "These are the toughest times that I have ever seen for students looking for a job," says E. L. Baughn, director of employment and college relations. Petroleum companies in general,

Help-wanted ads in C&EN up from 1991 low



[a] Column-inches published during consecutive periods of four weeks each; no issues were published in the last week of 1989, 1990, and 1991.

and Phillips in particular, have cut their recruiting plans 80 to 90% over the past couple of years, he says. Phillips, which used to hire 200 to 300 new college graduates each year, is looking for "something like 20 or 30" this year. Last year, it hired 35; the year before, more than 200.

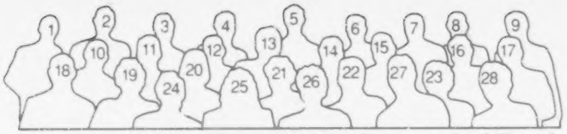
Unlike recruiters at many chemical companies, Baughn predicts that oil company recruitment may never return to the levels of the past. Although demand for new graduates will pick up, he expects it to stabilize for his company at about half of earlier levels. That same pattern holds for most petroleum companies, he says. "The unfriendly drilling environment in the U.S. today is driving jobs overseas in our industry even faster than is happening in the automobile industry," Baughn says. And as drilling moves abroad, so, too, will technical jobs.

This past year saw Phillips reduce its overall staff by 1500 people as part of a broad-ranging program to cut operating costs. This was but the most recent of several staff reductions and cost-cutting moves at Phillips in the past decade, Baughn points out. The company has been the target of repeated take-over attempts, all defeated, but at a cost in areas such as professional staffing.

Phillips isn't doing any campus recruiting this year, although the recruiting staff will be going to career fairs on college campuses this fall "to tell students that jobs are very minimal," Baughn says. He's hoping that "after the first of the year, we'll have some jobs."

Petroleum companies have traditionally been a major employer of chemical engineers. And engineering placement offices on college campuses confirm Baughn's assessment that recruiting by these firms is down sharply this year. "Petroleum companies haven't so much canceled their recruiting as cut way back on their schedules," says Sandra Arnn, director of engineering career services at the University of Wisconsin, Madison. Demand for chemical engineers continues strong at other types of employers, however, such as paper, pharmaceutical, and food processing companies. Chemical companies, too, still seem to be looking hard for chemical engineering graduates, she says.

Chemical and petroleum engineers have been the engineers in highest demand for the past several years. This year, at Wisconsin, that demand has shifted only slightly, so that chemical and environmental engineers now seem the most sought after. Last year, 42% of



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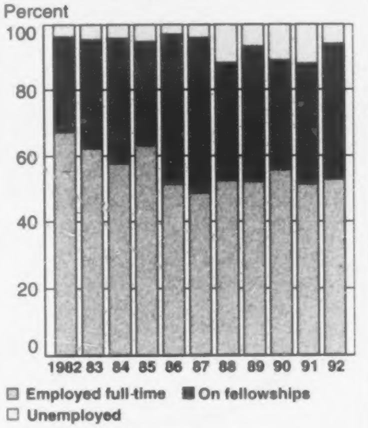
employers contacting her office were looking for chemical engineers, Arnn says. That preference is certainly holding this year, as well, she adds. "It seems as though the demand [for chemical engineering graduates] is going to continue," she says. Although the search may be somewhat more difficult than in past years, she's expecting all graduates in this field at Wisconsin will find jobs.

What happens to graduates when they can't find jobs? Judging by last year's example, most stay in school. ACS's starting salary survey, conducted last summer, found 49% of newly graduated bachelor's-level chemists intending to be in graduate school this fall, up from 42% the year before and from 36% in 1990. The picture was almost the same for chemistry Ph.D.s—43% of last year's graduates had accepted postdoctoral positions for this year, compared with 37% in 1991 and 34% in 1990.

Of course, postdoctoral experience is a usual step in the career progression of scientists preparing for research careers in academia, and some companies—Monsanto, for example—prefer to hire postdocs to fill their Ph.D. positions. But the recent, rapid buildup of Ph.D.s accepting postdoctoral appointments is beginning to cause some concern.

"In many fields—physics, mathematics, and computer sciences—there seem to be more people coming out with Ph.D.s than jobs available," says Alan Fechter, executive director of the National Research Council's office of scientific and engineering personnel. "In many cases these people wind up in postdocs as a temporary holding pattern. There's a big group of people out there in postdocs waiting for the market to open up. My fear is that they might be considered damaged goods. They might be at a disadvantage compared to someone just out of school."

Ph.D. chemists stay in school in tight job market



Note: Data as of the summer of each year.
Source: ACS annual surveys

And some Ph.D. candidates simply take longer to complete their degree. At the University of Wisconsin, Madison, for example, 45 Ph.D. candidates in chemistry signed up to interview with industrial employers last year. Of that group, nine found positions in industry; two took academic positions; and eight accepted postdoctoral positions, although only half really wanted the positions—the other half would have preferred a job in industry if they had found one, says Audrey L. Aylesworth, placement coordinator for the chemistry department. Of the remainder, 20 are back again this year, still working on a Ph.D., and still looking for industrial employment. There are always a few Ph.D. candidates signing up to see recruiters more than a year before they actually receive their degrees, Aylesworth says, but the number of returnees this year is unprecedented.

At the same time, formal unemployment—that is, the number of people who say they are actively looking for work and unable to find it—actually declined for new chemistry graduates last year at both the bachelor's and Ph.D. levels, according to the ACS survey. At the B.S. level, it dropped to 10.4% from 14.0% in 1991; for Ph.D.s, the decline was even more dramatic, going from 11.5% in 1991 to 4.5% this past summer.

When will the recruitment picture change? "If and when the economy changes," says Procter & Gamble's Logan, echoing the sentiment of most observers. And that's unlikely to be for at least a year, he adds. Dow's Townsend is predicting a pickup in hiring in 1994 and a return to "normal" levels for Dow by 1995. Mason expects Monsanto will have doubled its present entry-level hiring in five years, bringing hiring back to its prerecession levels. But whether that pickup will begin next year or somewhat later depends on the economy. ☐

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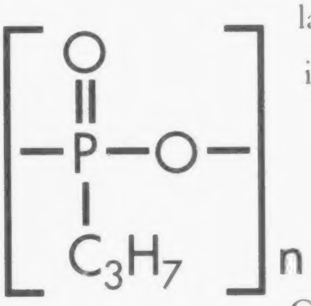

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CHEMICAL & ENGINEERING NEWS

C&EN

OCTOBER 26, 1992

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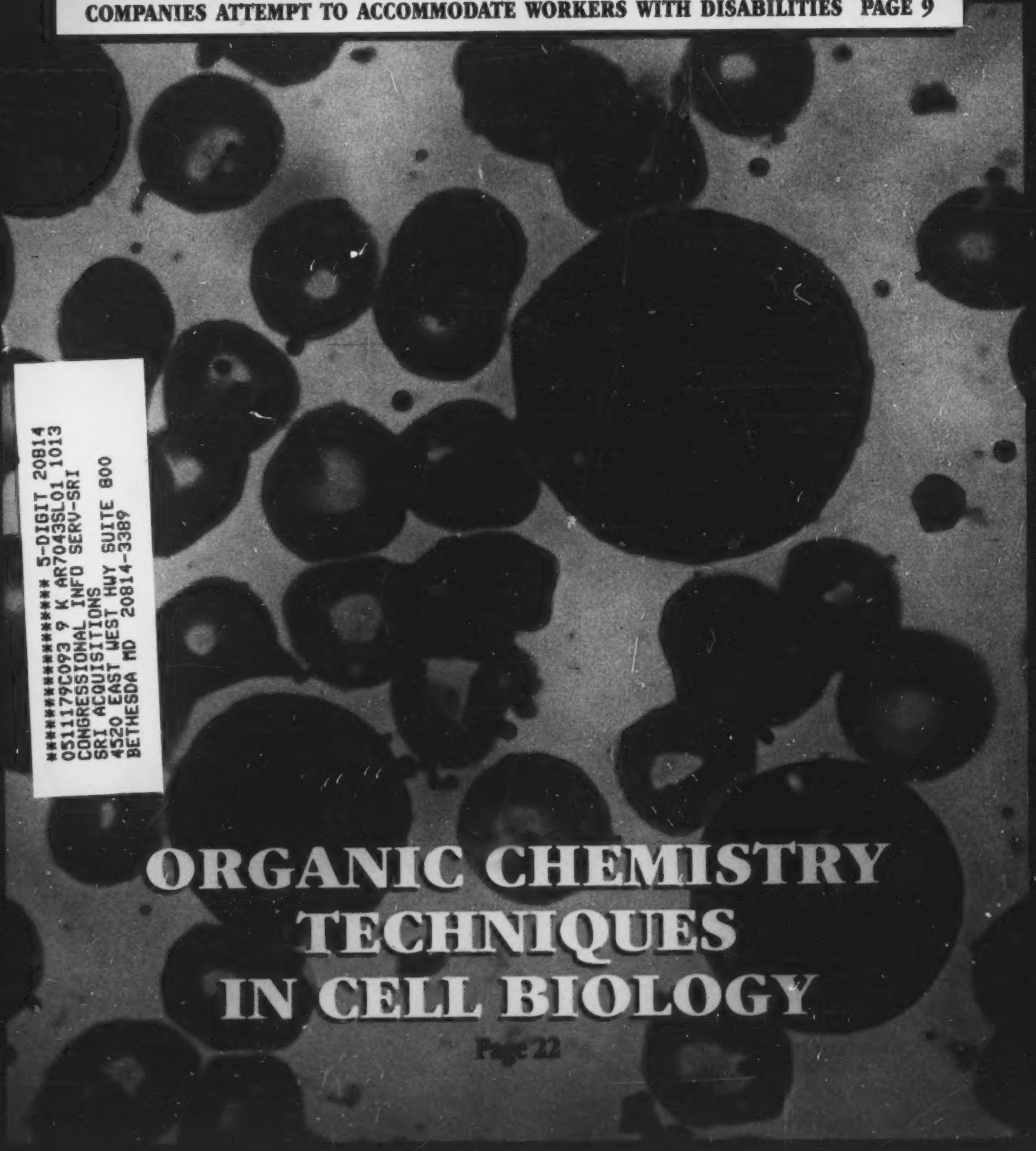

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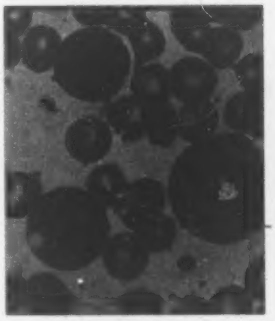

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Subscription Rates 1992: Printed editions: nonmembers U.S. 1 yr. $105, 2 yr. $189; outside U.S. 1 yr. $141, 2 yr. $261. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $15. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Racemic, scalemic polemic

The recent series of letters to C&EN on terms to describe mixtures of enantiomers that are not racemic was brought to the attention of the International Union of Pure & Applied Chemistry Commission III.2 (physical organic chemistry). The topic was discussed at the recent meeting of the commission in the context of its review of a draft "Glossary of Stereochemical Terms," which has been submitted by a working party on stereochemical terminology for approval by IUPAC.

In view of the extent and liveliness of the published correspondence, it was decided to anticipate a formal ruling by IUPAC and to communicate the present views of the commission on this matter informally in a letter to C&EN. As one of its representatives on the aforementioned working party, the task was assigned to me.

The correspondence is motivated by the need felt by several stereochemists to find alternatives to the currently used terms "enantiomerically pure" and "enantiomerically enriched." The use of "homochiral" for the former has met with universal disapproval and is specifically discouraged in the draft glossary, but the discussion seems to have gone off at a tangent with Clayton Heathcock's (C&EN, Feb. 4, 1991, page 3) revival of James H. Brewster's proposal of the term "scalemic" and the latter's amplification thereof (C&EN, May 18, page 3). Its proponents reject the generally accepted terms, as well as their contractions "enantiopure" and "enantioenriched" as "cumbersome." The difficulty is that it is not clear which of the two terms scalemic is intended to replace.

Takeshi Nakai (C&EN, July 1, 1991, page 2), for example, states that "scalemic and racemic comprise a pair of words that are the macroscopic counterparts of chiral and achiral," going to the unacceptable extreme of referring to "scalemic and racemic *molecules*." This view is presumably shared by Hubert Maehr (C&EN, Aug. 26, 1991, page 2), who proposes the unwieldly "ambiscalemic" for substances of unknown absolute configurations. In contrast, Brewster and Heathcock propose to invest scalemic with quantitative meaning, to the extent of setting up a "scalemicity scale." Evidently, to Nakai and Maehr scalemic means enantiomerically pure, whereas to Brewster and Heathcock it represents a variable degree of "enantiorichness," with "enantiopurity" specified as "100:0 scalemicity."

The proposal is criticized trenchantly by Guy Ourisson (C&EN, June 8, page 3), who points out that scalemic is an "etymological monster" but is careful not to advocate the use of the more correct "scalemic" because of the term's inherent ambiguity.

Enantiomerically pure and enantiomerically enriched are indeed cumbersome, but Robert S. Coleman's (C&EN, July 22, 1991, page 3) proposal of homoenantiomeric for the former and—by logical extension—isoenantiomeric for the latter is certainly no less so than the commonly used enantiopure and enantioenriched. We therefore propose that the latter contracted forms should be adopted officially as more concise alternatives to the full terms.

Ernest Eliel and Samuel H. Wilen (C&EN, July 22, 1991, page 3) argue that the distinction between enantiopure and enantioenriched is experimental, so a conceptual term is needed to describe macroscopic mixtures of enantiomers that are not racemic. They propose the term aracemic, which they recognize to be a Greek-Latin hybrid, in preference to the linguistically "purer" but less "crisp" nonracemic.

There can be no objection to referring to a sample of a chiral compound that is not racemic as being "non-racemic," but this is hardly a good enough reason for revising it to the etymologically infelicitous aracemic and introducing it as a separate term. This being said, we do not agree with Brewster that both forms of the term "clearly imply that racemate is an impurity" any more than achiral implies that a chiral molecule is abnormal. Therefore, if the need is felt for a purely qualitative term to describe any unequal macroscopic mixture of enantiomers, be it 51:49 or 99:1, we are prepared to go along with non-racemic, retaining the hyphen.

Since organic chemists now routinely apply nonoptical methods to the determination of enantiomeric and diasteriomeric ratios, we agree with Brewster that provision should be made for the direct expression of these ratios. However, there is no need to coin a new term such as scalemicity, for which there is no obvious diasteriomeric equivalent, when enantiomeric ratio and diasteriomeric ratio are self-explanatory. We propose the inclusion of these two terms in the glossary, retaining enantiomeric excess and diasteriomeric excess as well, since the older terms will probably remain in use for a long time to come.

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Disabilities Law Is Being Implemented By Companies as Needs Arise

■ ***Law granting equal job participation and access to the disabled is bringing about changes, but only gradually***

Ann M. Thayer,
C&EN Northeast News Bureau

The Americans with Disabilities Act (ADA) of 1990 went into effect Jan. 26, 1992. It is aimed at expanding civil rights protections and making workplaces, public facilities, and transportation accessible to 43 million people with disabilities. Starting this past July 26, any company with more than 25 employees is required to abide by the employment provisions of ADA. In two years, the law will extend to cover even smaller businesses--those with 15 to 25 employees.

Companies in the chemical industry independently have been laying the groundwork for complying with the law and now are putting it into practice. Before ADA's effective date, Dow, Du Pont, and Monsanto were among those companies that had put together ADA task forces. Such teams generally involved people from all areas of company operations who were brought together to address company policy, evaluate any necessary changes, and inform and educate employees at company sites.

Under ADA, individuals with disabilities must be provided access to all public accommodations and must be given equal opportunity in all aspects of employment. The law does not contain any affirmative action stipulations or quotas. Employers cannot discriminate against otherwise qualified people with physical or mental disabilities in hiring, promotion, compensation, training, or benefits. Employers are not required to change their health insurance policies if they apply equally to all employees.

A disability is broadly defined as having a record of, being regarded as, or having a physical or mental impairment which "substantially limits" one or more major life activities. Some specific conditions are considered disabilities: AIDS, epilepsy, paralysis, cerebral palsy, muscular dystrophy, multiple sclerosis, cancer, heart disease, diabetes, mental retardation, and some learning disabilities. Not included as protected disabilities are simple physical characteristics, pregnancy, some personality traits, a lack of education, or a prison record, but some emotional and stress-related illnesses are covered.

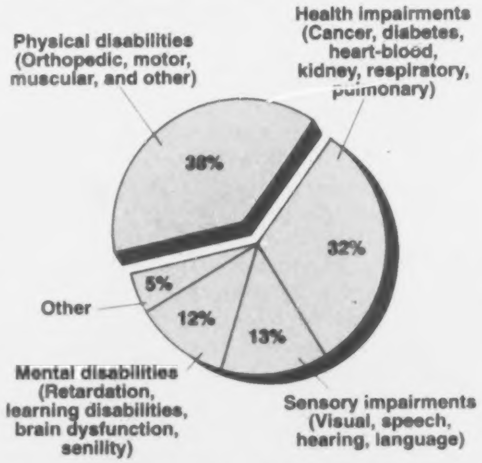
Past illegal use of drugs and alcoholism are covered as disabilities. Current illegal drug use is not covered and drug testing is allowed. An employer may deny employment or fire an employee if alcohol use adversely affects job performance or conduct. Occupational health and safety concerns can have a bearing on employment if there is a direct threat to an individual or to other employees.

Drug use as a covered disability under ADA is what Louise Perna, coordinator for disability programs in Du Pont's human resources department, calls a "gray area." It has not yet been determined, she explains, what rehabilitation programs are acceptable or after what drug-free period of time an individual can be considered recovered. Another such gray area is labor relations in which there may be conflicts between union agreements and what is required under ADA. There has been no agreement yet, Perna says, on how unions will be bound by the provisions of ADA.

In addition to the employment issues, most companies also must meet public accommodations provisions of the law. Immediate changes may be needed in company buildings or facilities that are open to the public, or in transportation. "Monsanto did make sure that tour routes at its various facilities were accessible," says Gwen Wesley, Monsanto's director for equal opportunity affairs, "and that the company's cafeterias and auditoriums were accessible because people . . . use Monsanto's facilities."

Determining exactly who has rights under ADA and what obligations fall to companies will be an evolutionary process for all involved, say human resource managers and management consultants. But for many companies, ADA does not present a radical departure in employment practices. Many chemical companies have had experience with employing the disabled under

Most working-age disabled people are physically impaired



1991 total = 13 million disabled people of working age

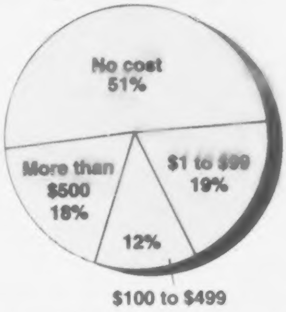
Source: National Council on Disability the Rehabilitation Act of 1973, which covers all federal employees and companies with government contracts of more than $50,000. But, because ADA extends much beyond the Rehabilitation Act, there is concern about companies using it as an excuse not to make changes.

In a 1992 Hay Group survey of human resources managers at 32 chemical companies, more than half said adapting to work force diversity was important, but not considered a priority and ranked well below other personnel management issues. "It's probably going to have to be like other civil [rights] legislation that's been passed, in the sense that a number of companies are going to have to be penalized or something is going to have to happen that focuses the attention on [ADA]," says Thomas McCarthy, managing director of the chemical industry practice at Hay Management Consultants in Philadelphia. "If EEOC [the Equal Employment Opportunity Commission] does not take an active role, I suspect that not much will change," he adds. "[ADA] is subject to such varied interpretation that it is going to be years before there is enough substance and practice established to give companies guidance on what to do."

Under ADA, employers must make sure their employment practices do not present any bias against disabled individuals. Job applicants or employees cannot be asked about their disability or medical history, and preemployment medical exams have been limited greatly. A job offer can be conditioned on the results of a medical exam as long as the exam relates directly to the tasks of the job. All medical information must be kept confidential and segregated from an employee's records.

Employers may ask what accommodations, if any, are necessary for a qualified individual to perform the "essential functions" of a job. "Outside the compliance with architectural and facilities concerns, most organizations are taking a serious look at the duties and responsibilities of various jobs," says Charles Lee, vice president at New York City-based management consulting firm Towers Perrin. "The good news is that they haven't done that for a long, long time and they need to. It will give them a chance to focus on new technology that exists as well as on the actual steps necessary to accomplish the mission of a job."

Most costs of changes for disabled workers small



Source: Equal Employment Opportunity Commission

An employer must provide "reasonable accommodations" as long as they do not present an "undue hardship" for the company. The biggest challenge for many companies may be thinking of jobs in terms of essential functions, says a spokesman for EEOC, but, once accomplished, understanding what accommodations are needed, be they physical changes or otherwise, will become a natural part of the process. EEOC oversees the employment-related aspects of ADA, whereas the Department of Justice and the Department of Transportation will handle public accommodations and public transportation aspects, respectively.

Monsanto, Dow, and Du Pont are, as the law advises, defining the essential functions of a job on a case-by-case basis as job positions are advertised. And, rather than trying to make sweeping changes to accommodate hypothetical disabled employees, which would be costly and ineffective, the companies intend to respond to the needs of specific employees when they arise. "Organizations aren't usually comfortable with being responsive," says Lee. "They like to think they can plan for everything, but [ADA] doesn't allow for much planning except to train managers and employees to recognize that there will be people with disabilities coming to work."

Another challenge, possibly over and above management's willingness or unwillingness to accommodate disabled employees, says McCarthy, may be employee attitudes. "Some companies probably need to assess the attitudes of their employees toward people with disabilities," he says. "Companies can make all the accommodations necessary, they can go through job descriptions and sanitize them and identify the essential functions, they can change the physical layout of their buildings or their plants, and they can change their policies to make certain that discrimination is not an accepted practice, but the working relationship of employees with disabled workers is a big obstacle to overcome."

As with other parts of the law, ADA guidelines for accommodations are not specific in defining what is considered reasonable or an undue hardship. And a great deal of discussion and concern has centered on the potential costs of accommodations, which can include modifying facilities. What will be considered an undue hardship will depend on the nature of an accommodation, the size of the company, and the company's financial status, and has not yet been determined by Monsanto, Dow, or Du Pont.

The majority of "reasonable accommodations" cost less than $100, says a spokesman for EEOC, with more than 80% costing less than $500. In addition, there are tax credits for making accommodations, but these offer benefits only to small companies. Companies with less than $1 million in revenues or fewer than 30 employees can gain tax credits of up to $5000 on qualified expenditures of $10,000. Under Internal Revenue Service codes, companies spending on access for the disabled can take a tax deduction of up to $15,000 for removing architectural barriers to the handicapped.

Human resources managers and management consultants all say the actual cost of many accommodations can be low. "In most cases, it's a matter of creativity," explains Perna. "A lot of people will be quick to purchase a specially constructed water fountain when the only thing really needed was a [paper] cup dispenser." Cost has not been an issue in accommodations made thus far at Dow, adds Rita Shellenberger, Dow's manager of personnel diversity, and major modifications of bathroom facilities and elevators were something the company had already been doing. Monsanto's data regarding its accommodations are limited, says Wesley, because the company has not bothered tracking costs.

Accommodation need not only include removing barriers or other such physical changes, but also can mean changing work schedules, reorganizing nonessential job functions, altering training programs, or providing assistance such as readers or alternative materials. Companies say one valuable source of suggestions for accommodations and assistance for businesses in hiring disabled people is the Job Accommodation Network, Morgantown, W.Va., a branch of the President's Committee on Employment of People with Disabilities. EEOC's ADA Services division is preparing policy guidelines on some of the more vague aspects of the law, such as insurance, workmen's compensation, medical inquiries, and drug testing.

Compounding the apprehension surrounding ADA is that the financial stakes for not complying could be high. Available remedies—making required accommodations, hiring, reinstatement, compensation, or legal action—fall under the provisions of the Civil Rights Act and allow for damage awards of up to $300,000 against larger companies. Enforcement is expected to be driven by employee complaints filed with EEOC, which will review violations on a case-by-case basis. EEOC anticipates more than 12,000 new complaints per year, or about a 20% increase. In the first few months after enactment, says EEOC, more than 250 complaints were filed nationwide.

A prevalent attitude holds that ADA's fine points will be defined inevitably in the courts. Unlike other civil rights actions, lawsuits are expected to be on behalf of individuals, rather than class action suits, because it is difficult to group individuals in terms of disabilities. Others hope that, rather than through litigation, reconciliations and accommodations will be met through negotiation with EEOC and with individuals filing complaints. Experience under the Rehabilitation Act, says Lee, suggests that most employers will want to resolve any issues and that major lawsuits will not result.

Although many observers bemoan the government's intervention with yet another regulatory burden, many others say ADA offers an opportunity that will help to expand the pool of qualified workers. Du Pont has surveyed its work force for the past 35 years to evaluate the effectiveness of its more than 3000 disabled workers. In the latest survey from 1990, about 90% of disabled workers equaled or exceeded the performance of nondisabled workers as related to safety, job performance, and attendance. However, the law has gone into effect at a time when hiring is sluggish and it may take time before any impact on the number of disabled employees is seen. ☐

Arco Chemical Americas chief plans cost cuts

Marvin O. Schlanger may be new to the Arco Chemical Americas unit, but he is not unfamiliar with the operating, marketing, and regulatory challenges facing it. The newly appointed president of the Arco unit formerly served as Arco Chemical's chief financial officer. In his first interview with C&EN since assuming his new role, Schlanger outlined his plans to cut costs, increase productivity, and find markets to use new production just coming on line in Channelview, Tex.

Schlanger succeeds John G. Johnson Jr., who resigned in September to pursue other interests. Johnson left his successor a sizable company with $2 billion in 1991 sales, representing about 65% of Arco Chemical's nearly $3 billion in annual sales. In addition to Arco Chemical Americas, which produces products in the U.S. for sale throughout the Western Hemisphere, Arco Chemical consists of two smaller geographic units—Arco Chemical Europe and Arco Chemical Asia Pacific.

The Americas unit is a business that, like Atlantic Richfield Co.—which owns 84% of the chemical company—is preoccupied with lowering the cost of doing business in this recession. And like other chemical industry competitors, the Arco Chemical units must deal with slow demand for their products, which has, in turn, curbed profit margins in these uncertain times.

The recession has hurt, as did a 1990 fatal accident at Channelview that temporarily shut down production at the site (C&EN, July 16, 1990, page 4). Arco Chemical Americas' sales increased 2% a year from 1989 to 1991 to $2 billion, and annual operating earnings declined 5% a year during the same period to $379 million in 1991. That is in contrast to the "go-go" years between 1986 and 1988 when Arco Chemical Americas registered a compound annual sales growth of 22%, reaching more than $2 billion. Compound annual operating earnings growth for the period was 34% or $664 million. (Arco Chemical's shares started trading publicly in October 1987.) In the first six months of this year, Arco Chemical Americas' sales were up 5% to $975 million compared with the same period a year ago, whereas pretax earnings rose 4% to $192 million.

Schlanger: find new product applications

Slow business and excess capacity is a problem that Schlanger acknowledges he will have to deal with. "Clearly we have added a lot of capacity to our system." Their new Channelview plant—a large one, coming as it does at a time when industry growth has slowed from the heyday of the late 1980s—is now coming on line. It will add more than 1 billion lb of styrene production, almost doubling the company's current U.S. styrene capacity. It will also add 500 million lb of propylene oxide, effectively increasing Arco's U.S. capacity almost 30% (C&EN, March 2, page 9).

As a result, capital spending will drop for Arco Chemical overall from the $400 million to $600 million the company had been spending annually to $250 million for this year and next. Schlanger explains: "We've made a big investment in our assets base, and we want to get these assets productive. [Also] markets are not growing as fast as we thought they would a few years ago, so we can defer a number of market-driven projects without giving up our long-term market share."

Schlanger says Arco Chemical is working with customers to "find new applications for [our] products to grow the markets and increase our capacity utilization." He says the company has had some success in promoting propylene glycol, which has a lower toxicity profile, as a replacement for ethylene glycol in aircraft deicing and automotive coolant applications. "We have a number of regional distributors who are pro-

Congress Holds Federal R&D Funding At Current Level for Fiscal 1993

■ ***Zero increase in total R&D budget may be omen of the future as legislators act on notion that research must be useful***

Janice R. Long, C&EN Washington

Congress enacted all of the 13 appropriation bills needed to fund the federal government in fiscal 1993 before it adjourned on Oct. 9. The result for the research community can best be described as bleak. But money wasn't the only subject of attention during those last few days of the 102nd Congress. Lawmakers also completed work on a new national energy policy, a major tax bill (C&EN, Oct. 12, page 9), and a number of other bills of interest to the chemical community.

The overriding themes in the fiscal 1993 research appropriation bills—competitiveness, critical technologies, technology transfer, the idea that research must be "useful"—may foreshadow the future direction of the federal research enterprise. In addition, the zero increase in total research funds set by Congress may not be just an aberration but an omen of things to come.

Contributing heavily to holding the line in total research funding is a 1% decline, to less than $38 billion, for the Department of Defense's research, development, test, and evaluation programs. With the end of the Cold War, Congress is looking for ways to ease the conversion of the military establishment and defense industry into the domestic economy. One way of doing this is to focus Defense's research programs on critical dual-use technologies that can benefit U.S. defense as well as contribute to U.S. economic and industrial competitiveness. Congress directed that $861 million, or 2% of the R&D budget, be spent on such projects in fiscal 1993, including $30 million for advanced materials synthesis and processing, $65 million for high-temperature superconductor and diamond materials, and $100 million for a manufacturing extension program. That percentage is sure to grow in the coming years.

Defense's research budget also includes $635 million for health research, including $210 million for breast cancer research and $56.9 million for AIDS research by the Army. Funding for university research initiatives will be $325 million, a 2% increase over current funding.

The Congressional emphasis on competitiveness also surfaced in determining the National Science Foundation's 1993 appropriation. NSF has long been noted for its support of basic research performed by individual investigators. However, conference committee members assigned to resolve differences between the House and Senate versions of NSF's budget, noted a report by the National Science Board (NSB) on the strength of U.S. industrial R&D (C&EN, Aug. 17, page 7), which concludes that the U.S. spends too few dollars on R&D in industrial science and technology; does not allocate R&D expenditures well; and does not utilize its investment effectively. "If NSF is to help transform this condition, it seems apparent that it must, in fact, change the fundamental emphasis it places on various research initiatives," the conferees wrote.

The Senate had decided to change NSF's emphasis unilaterally. Its version of the appropriation bill contained a number of directives aimed at increasing NSF's ties with industry and focusing its activities on "technologies deemed to be critical to the nation's future." However, those directives were forestalled because NSF is, itself, seeking to redefine its role as evidenced by NSB's establishment of a commission on the future of NSF (C&EN, Aug. 24, page 6). The conferees agreed to set aside the Senate directives until the commission finishes its work—but warned that any changes it recommends must be "serious, substantive, and broad-based in the foundation's approach to R&D."

These efforts to reform NSF are set against the backdrop of the first cut in many years in funding for NSF's research and related activities, which declines 1% to $1.9 billion in 1993. Funding for education and human resources increases 5% to $488 million, and that for instrumentation and facilities rises 52% to $50 million. A Senate provision that called for spending $55 million on a new NSF defense conversion traineeship program for defense engineers was dropped from the final appropriation bill.

Another Senate-approved defense conversion program was dropped from the National Institute of Standards & Technology's (NIST's) appropriation as well. That $109 million program, which would have been funded out of savings from cutbacks in defense spending, was intended to capitalize on the agency's technology extension programs to facilitate the conversion of parts of U.S. industry to nondefense manufacturing. The program was deleted only because the Office of Management & Budget warned that it actually involved "domestic discretionary" spending, subject to strict budget controls, and its enactment would trigger an across-the-board cut in all the programs funded under the bill. However, NIST still posts the highest increase, by far, of any research funding agency. Its 1993 budget increases 56% to $384 million.

Funding decisions for the other research agencies were relatively straightforward, if disheartening to the research community. For the first time in years, a funding increase for the National Institutes of Health won't even keep up with a very low rate of inflation. Its budget rises just 2% to $10.3 billion, with funding for the human genome sequencing project up 1% to over $106 million. The National Aeronautics & Space Administration's research budget is also up just 1% to $7.1 billion, as funding for the space station rises 5% to $2.1 billion. The

Federal research budgets very tight in 1993

$ Millions	1993 Appropriation	1993 Request	1992	% difference Appropriation-request	% change 1992–93
Defense R&D	$37,962.2	$38,626.4	$38,765.9	−2%	−1%
Tactical programs	13,518.9	13,241.1	14,742.7	2	−8
Intelligence and communications	4,794.1	5,011.2	5,201.4	−4	−8
Technology base	4,517.8	4,083.9	4,184.8	11	8
Defensewide mission support	4,331.8	3,960.8	3,846.8	9	13
Strategic programs	4,148.1	4,507.1	4,278.7	−8	−3
Strategic Defense Initiative	3,613.1	5,312.4	3,321.3	−32	9
Advanced technology development	3,038.4	2,509.9	3,090.2	21	−2
NIH	10,322.8	10,579.7	10,071.6	−2	2
National Center for Human Genome Research	106.4	110.4	104.9	−4	1
NASA R&D	7,075.0	7,687.4	7,004.7	−8	1
Space station	2,088.9	2,238.9	1,986.8	−7	5
Energy	6,683.0	6,684.6	6,357.1	0	5
Energy R&D	5,416.9	5,270.4	4,924.5	3	10
General science and research	1,471.8	1,652.7	1,472.5	−11	0
Superconducting Super Collider	517.0	650.0	483.7	−20	7
Supporting research and technical analysis	966.4	971.6	867.2	−1	11
Basic energy sciences	859.7	813.9	764.7	6	12
University and science education programs	55.7	55.7	54.5	0	2
Environmental restoration and waste management	709.7	707.0	602.5	0	18
Fossil fuels	421.9	311.3	452.3	36	−7
Environmental R&D	356.7	384.7	353.7	−7	1
Fusion	339.7	359.7	337.1	−6	1
Conservation	314.8	326.1	260.1	−3	21
Nuclear	311.4	310.3	336.7	0	−8
Solar, other renewables	254.5	247.0	242.8	3	5
Weapons R&D	1,536.1	1,414.2	1,432.6	9	7
NSF	2,555.5	2,888.0	2,465.8	−12	−4
Research and related activities	1,859.0	2,211.5	1,879.8	−16	−1
Education and human resources	487.5	479.5	465.0	2	5
Antarctic program	158.0	163.0	88.0	−5	80
Instrumentation and facilities	50.0	33.0	33.0	52	52
Critical Technologies Institute	1.0	1.0	0	0	100
USDA	1,361.9	1,300.1	1,396.7	5	−2
Agricultural Research Service	695.4	714.0	711.5	−3	−2
Cooperative State Research Service	482.2	416.0	504.7	16	−4
Forest Service research	184.3	170.1	180.5	8	2
Commerce	586.2	504.4	459.7	16	28
National Institute of Standards & Technology	384.0	310.7	246.7	24	56
Oceanic and atmospheric research	202.2	193.7	213.0	4	−5
EPA R&D	323.0	338.5	320.9	−5	1
TOTAL	$66,869.6	$68,609.1	$66,842.4	−3%	0%

Source: Congressional reports on fiscal 1993 appropriation bills

Environmental Protection Agency's extramural research budget is also up just 1% to $323 million, and the Department of Agriculture's research budget is down 2% to $1.4 billion. Compared with these agencies the Department of Energy's budget for energy R&D looks positively rosy, with an overall increase of 10% to $5.4 billion.

However, even as Congress was holding research funding increases to a bare minimum, it continued to earmark millions of dollars for projects at specific academic institutions. Sen. Sam Nunn (D.-Ga.), chairman of the Senate Armed Services Committee, objected strenuously during debate on the conference report on the Defense Department's appropriation bill to language inserted by House conferees mandating the expenditure of some $196 million for projects at 31 colleges and universities. That includes $95 million for 10 projects that Rep. George E. Brown Jr. (D.-Calif.) had been successful in having deleted from the conference report on the Energy Department's appropriation bill.

The $95 million is split, just about evenly, among the following 10 projects:

- Bishop Science Center, Hawaii.
- Ambulatory Research & Education Building, Oregon Health Sciences University, Portland.
- Center for Energy & Environmental Resources, Louisiana State University, Baton Rouge.
- Advanced Technologies Institute, University of Connecticut, Storrs.
- Biomedical Research Facility, University of Alabama, Tuscaloosa.
- Cancer Treatment Facility, Indiana University School of Medicine, Indianapolis.
- Cancer Institute of New Jersey.
- Northeast Environmental Resource & Renewal Facility, Mayfield, Pa.
- Center for Advanced Industrial Processes, Washington State University, Pullman.
- Hahnemann University Ambulatory Care & Teaching Center, Philadelphia.

Both NASA's and EPA's appropriation bills are also riddled with apparent earmarks for various research projects, though it quite often is hard to tell whether the funds represent Congressional additions to funds requested by the federal agency in question or if they are for entirely new projects the agency never heard of.

For example, the House-Senate conferees directed NASA to spend $10 million for the University of Utah Intermountain Network & Scientific Compu-

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tation Center; $4.5 million "for the Oregon system of higher education for computer network infrastructure for advanced technology and education projects"; and $400,000 from its Earth sciences research and analysis budget for the University of Nebraska, Lincoln.

EPA was told to spend $700,000 for urban waste management research at the University of New Orleans; to fund a $1.45 million pollution prevention R&D center at the University of Georgia, Athens; and to spend $1.6 million with the University of North Dakota, Grand Forks, for a cradle-to-grave assessment and control technology development program for toxic metal emissions. The list of projects contained in the various appropriation bills goes on and on.

Nunn called these and the other 21 House earmarks a "slap in the face of good government," adding that the message Congress is sending to colleges and universities is that "the sure way to be funded is not through excellence or performance or through merit-based selection: The way to be funded is through the office of a member of Congress, regardless of the value and the merit of the proposed research." He pointed out that the seven Senate earmarks, totaling about $75 million, do not mandate expenditures but rather leave it up to the Secretary of Defense to decide whether the projects merit funding.

Among the other bills cleared by Congress in the final days of the session was S. 2941, which expands the small business innovation research (SBIR) program. The bill gradually increases the percentage of extramural R&D budgets that federal agencies with annual R&D budgets of $100 million or more must set aside for the program, beginning at 1.5% in fiscal 1993 and 1994, rising to 2% in 1995 and 1996, and finally to 2.5% in 1997 and thereafter. The maximum size of a phase 1 SBIR award rises from $50,000 to $100,000 and that of a phase 2 award from $500,000 to $750,000. Federal agencies whose R&D budget exceeds $1 billion are required to initiate a pilot technology transfer program to fund cooperative R&D projects involving a small company and a researcher at a university or at one of the contractor-operated national labs.

Other bills that Congress passed include one that makes it clear that states and their officers or employees can be sued for patent or copyright infringement and, if found guilty, must pay the same penalties as any private entity;

one that authorizes a $35 million NSF grant program for community colleges interested in upgrading their science and technical education programs and in obtaining state-of-the-art instrumentation; one that creates an NSF research program to develop membrane processes for treating contaminated water; and another that increases the base rate for the excise tax on ozone-depleting chemicals to $3.35 per lb in 1993, $5.35 per lb in 1995, and by 45 cents per lb per year thereafter.

In addition, the Senate ratified a United Nation's treaty, signed by President Bush at the Rio Earth Summit, that requires signatory countries to report on the efforts they are making to limit emissions of "greenhouse gases." And Congress altered a law requiring cleanup of hazardous waste on federal lands before any portion can be sold or transferred to local governments or private entities, by permitting the sale of uncontaminated parcels prior to total cleanup. Bush is not expected to sign that bill.

Flaws cited in NIH gene patent application

The National Institutes of Health may be able to clear up some of the weaknesses that caused the Patent & Trademark Office to reject the agency's first stab at patenting partial genetic sequences. But the final decision is likely to be the same as the patent office's initial reaction, according to a lawyer familiar with the case: No patent.

On Aug. 20, in what is called a "first office action," the patent office rejected NIH's application for patents on thousands of partial human gene sequences, most of whose functions are unknown. NIH had sought to patent the research work of former NIH researcher J. Craig Venter and coworkers so the scientists could share their data with others without forfeiting intellectual property rights. The application attracted bitter disapproval from critics who fear it will inhibit free flow of information among scientists (C&EN, June 8, page 21).

Such first-round rejections happen all the time, according to Henry Wixon, a Washington, D.C., patent lawyer active in the Association of Biotechnology Companies (ABC) patent affairs committee. Neither NIH nor the patent office has released the decision, but Wixon, who has seen a copy, reviewed it at a recent ABC forum. NIH will attempt to answer the patent examiner's objections and the back-and-forth reiteration will be repeated several times before a final decision is laid down, he said.

The examiner's initial rejection of the NIH gene fragment patent is clear-cut. Wixon said it characterizes the application's claims as "vague, indefinite, misdescriptive, inaccurate, and incomprehensible." The application itself admits the gene sequences in question have a low probability of encoding polypeptides and may contain errors, he said.

The decision says the application failed to make the case that the claimed invention was novel, had utility, and was nonobvious, according to Wixon. Venter, who has left NIH and now heads the private Institute for Genomic Research, told the ABC forum that he was particularly concerned about the ruling on obviousness.

"The ruling was that all our sequences are obvious because [the patent office] found random 15-mers [15-base fragments] that match our sequences in databases," Venter said. He has proposed that Congress change U.S. patent law so that full genes can be patented even if such fragments have already been published.

The decision also brought into the open the dispute over the controversial patent application between NIH and its parent agency, the Department of Health & Human Services, which would like the application withdrawn. The patent examiner refers to a June letter from HHS general counsel Michael J. Astrue that says the application may not be strong enough to warrant a patent.

"NIH shouldn't be second-guessed," Wixon said. "It would be unfortunate if Astrue succeeds and the government pulls the claim before we can have a full discussion of the issues."

However, Wixon predicted the application will ultimately be rejected even if NIH tries to revise it to meet the patent office's objections. "This issue is too hot for the patent examiner to allow it," he said. "He will kick it up to the Board [of Patent Appeals & Interferences]. And they may kick it up to the U.S. Court of Appeals."

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